University of Alberta

EEG Characteristics of Attention Deficit Disorders With and Without Hyperactivity

by

Garth Allan Stewart

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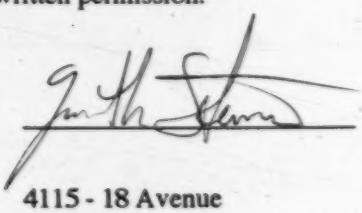

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This thesis is dedicated the Lord Jesus Christ and to the members of my family:

To my wife, Caroline, without whom none of this would have been possible. Your patience, encouragement, and support have not gone unnoticed.

To my sons, Cameron and Graham, who were an inspiration for me to work diligently to ensure that I graduated before they did.

To my parents, who modeled the type of courage and character that is required to successfully face life's challenges.

Abstract

The purpose of the study was to examine the external validity for Attention Deficit/Hyperactivity Disorder (ADHD), Predominantly Inattentive Type, as a separate entity from ADHD, Combined Type. EEG and psychometric data were collected on a group of carefully selected 10 to 12 year old boys who met the criteria for one of these two diagnoses, as well as a group of normal control children. The EEG records were collected during the following three conditions: eyes open, eyes closed, and while completing the Test of Variables of Attention (TOVA). Means and standard deviations were calculated for each EEG variable and change scores were calculated to reflect the shift in EEG activity that occurred between the eyes open and TOVA conditions. An analysis of covariance design using the eyes open condition as covariate was also used to compare the EEG data for the three groups. Both of the clinical groups obtained similar scores on the TOVA and exhibited the presence of excessive slow wave activity and higher mean magnitude when compared to normal subjects. The majority of significant differences emerged between the predominantly inattentive subjects and the control subjects. The results do not provide support for conceptualizing ADHD, Predominantly Inattentive Type, as a distinct clinical entity. The findings are discussed in relation to the theory of optimal stimulation and its possible relevance to understanding the different behavioral presentation of the two clinical groups.

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CHAPTER I

INTRODUCTION

Attention Deficit/Hyperactivity Disorder (ADHD) is one of the most common of all the childhood behavior disorders. Although prevalence estimates have varied widely, a recent study of a large community sample found that 9% of males and 3.3% of females between the ages of 4 and 16 could be diagnosed with ADHD (Szatmari, Offord, & Boyle, 1989). More conservative estimates place the prevalence at 3% (American Psychiatric Association, 1987). The disorder has a long and somewhat confusing history, having been referred to variously as Minimal Brain Dysfunction (Bloomingdale & Bloomingdale, 1980), Childhood Hyperkinesis (Mattes, 1980), Hyperactivity (Zentall, 1975) and the Hyperkinetic Reaction of Childhood Disorder (American Psychiatric Association, 1968). In fact, Denhoff (1977) identified 17 different labels that had been applied to this population of children up to that time.

Based on the observation that an inability to sustain attention and impulsivity were more prominent symptoms than excessive motor excitability (Douglas, 1972; Douglas & Peters, 1979; Spitzer & Cantwell, 1980), the term Attention Deficit Disorder was adopted by the 3rd Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-III; American Psychiatric Association, 1980). Two subtypes of the disorder were included, Attention Deficit Disorder with Hyperactivity (ADD/H) and Attention Deficit Disorder without Hyperactivity (ADD/WO), to reflect

the presence or absence of the hyperactivity component. With the publication of DSM-III-R (American Psychiatric Association, 1987), the distinction between these two subtypes was effectively removed by the adoption of a unidimensional category referred to as ADHD. The rationale for this change was that in field trials the clinical diagnosis of ADD/WO was rarely made, and thus it was concluded that there was little need for the category. Instead, a new diagnosis called Undifferentiated Attention Deficit Disorder (UADD) was created which would presumably include some of the disturbances that would previously have been classified as ADD/WO.

Although some of the available research supported this change (Maurer & Stewart, 1980; Rubenstein & Brown, 1984), many investigators and clinicians viewed this decision as a step backward (Epstein, Shaywitz, Shaywitz, & Woolston, 1991). Most recognized that the category of attention disorders was comprised of a relatively heterogeneous population, and the DSM-III-R criteria only served to blur the distinctions between suspected subtypes. Under this system a child could be diagnosed as ADHD if he or she displayed at least eight of the 14 symptoms that pertain to difficulties in attention, impulsivity, or hyperactivity. As a result, it was not necessary for all three of these components to be present in order to make a diagnosis of ADHD, and a child who did not exhibit any symptoms of hyperactivity could still qualify for the diagnosis if a sufficient number of symptoms of inattention and impulsivity were present (Lahey et al., 1988). Thus both ADD/H and ADD/WO children could receive a diagnosis of ADHD, which, in both research and clinical samples, may have resulted in the identification of a somewhat heterogeneous

population, possibly reflecting two separate disorders (Hynd et al., 1991). Indeed, a significant proportion of the research literature on ADHD does not clearly specify the precise nature of the symptoms exhibited by the subjects included in their samples, making it difficult to appropriately interpret the findings and to compare the results with those of other studies. In response to such concerns the distinction between ADD/H and ADD/WO was reinstated with the publication of DSM-IV (American Psychiatric Association, 1994). Under this system it is possible to specify three different subtypes of ADHD based on the presence or absence of 18 symptoms (nine for inattention and nine for hyperactivity-impulsivity). The Predominantly Inattentive Type is indicated when six or more symptoms of inattention but fewer than six symptoms of hyperactivity-impulsivity are present. The Combined Type is appropriate in cases where at least six symptoms of inattention and at least six symptoms of hyperactivity-impulsivity are present. A third option, the Predominantly Hyperactive-Impulsive Type, is used when there are six or more symptoms of hyperactivity and impulsivity, but fewer than six symptoms of inattention. However, individuals who qualify for the latter subtype may still present as being significantly inattentive. Although this most recent revision in classification schemes will undoubtedly facilitate greater specificity in diagnosing attentional disorders, it is still not clear whether ADD/WO represents a subtype of ADHD or whether it warrants recognition as a separate disorder. Furthermore, there is a lack of evidence to support the validity of ADD/WO as a subtype of ADHD.

The need for valid and clinically useful diagnostic categories within clinical psychology and psychiatry is self-evident. Without a clear description of the symptoms typically associated with a given disorder and comprehensive guidelines outlining the criteria for inclusion within a specific category, concentrated research activities, effective communication between professionals, and the consistent application of appropriate treatment regimens would be next to impossible to achieve. In this regard, the U.S. Interagency Committee on Learning Disabilities recognized the importance of research that is

> oriented to the development of a classification system that more clearly defines and diagnoses learning disabilities, conduct disorders, and attention deficit disorders, and their interrelationships. Such information is a prerequisite to the delineation of homogeneous subgroups and the development of more precise and reliable strategies for treatment, remediation, and prevention that will increase the effectiveness of both research and therapy. (Quoted in Fletcher, Morris, & Francis, 1991, p. 73)

From both a theoretical and a clinical standpoint it would be important to establish the external validity of ADD/WO as a disorder that is different from ADD/H in some clinically meaningful way, if indeed ADD/WO deserves such status. As it stands now, much of the research on the attention disorders collapses both ADD/H and ADD/WO subjects into the ADHD category, possibly confounding the samples with a heterogeneous population comprised of subjects with different disorders (Hynd et al., 1991). Validation of ADD/WO may lead to more stringent sample

selection criteria in future studies, help to guide research into the etiologic factors associated with these behavior disorders, and assist with efforts to identify more appropriate intervention strategies and techniques that may be differentially effective. The various changes in the diagnostic criteria for attentional disorders that have occurred over the past two decades have also had a significant impact on the reported prevalence of ADHD in the general population. Baumgaertel, Wolraich, & Dietrich (1995) found that the prevalence of ADHD in a sample of German children increased by 64 % when DSM-IV criteria was used rather than the old DSM-III-R criteria. This increase was primarily attributed to the inclusion of the Predominantly Inattentive category under DSM-IV criteria. These findings serve to highlight how changes in diagnostic criteria can have a significant impact on who receives the diagnosis and how many children are included in a diagnostic category. They also underscore the importance of validating new categories such as ADD/WO to ensure that they are clinically meaningful and provide greater precision in both diagnosis and treatment.

For ADD/H and ADD/WO to be considered as two separate disorders, or even two subtypes of the same disorder, it is necessary to identify significant differences with respect to their correlates, etiology, prognosis and course, or response to treatment (Lahey & Carlson, 1991). Fletcher et al. (1991) have outlined three separate components of classification research: 1) theory formulation, which involves the selection of relevant variables or attributes thought to distinguish between the two groups; 2) internal validity, which refers to the reliability and

replicability of the proposed classification; and 3) external validity, which is concerned with whether the proposed groups can be differentiated on measures other than those used to initially formulate the groups. In order for it to be considered a separate diagnostic category, the internal and external validity of ADD/WO must be demonstrated.

The purpose of the current research study was to evaluate the external validity of ADD/WO as a disorder that is distinct from ADD/H by examining the electroencephalographic (EEG) characteristics of ADD/H and ADD/WO children during the completion of a computerized attention task. As EEG characteristics would be independent from the criteria used to arrive at an initial diagnosis, successful differentiation on such a measure would help satisfy the requirements for external validity as outlined by Fletcher et al. (1991). Differences between these two groups on the attention task as well on measures of intelligence and academic achievement are also explored.

CHAPTER II

REVIEW OF THE LITERATURE

There have been a number of published literature reviews that have examined this issue (Carlson, 1986; Dykman & Ackerman, 1993; Lahey & Carlson, 1991; Goodyear & Hynd, 1992; Schaughency & Hynd, 1989), and in each case the authors concluded that there is sufficient evidence to suggest that ADD/H and ADD/WO likely represent distinct clinical entities. However, the majority of the evidence supporting this view comes from observed differences between these two groups with respect to overt behavior, comorbid diagnoses, and familial patterns of psychiatric disturbance. The following is an examination of what is currently known about the differences and similarities between ADD/H and ADD/WO. For the purposes of clarity, hyperactive subjects will be referred to as ADD/H and nonhyperactive subjects will be referred to as ADD/WO even though the original studies may have used different designations. It has been shown that ADD/H subjects as identified by DSM-III criteria correspond to the Combined Type of ADHD while ADD/WO subjects correspond to the Predominantly Inattentive Type according to DSM-IV criteria (Morgan, Hynd, Riccio, & Hall, 1996).

Demographic Variables

Research has generally found ADD/WO and ADD/H samples to be similar with respect to race and socio-economic status (Lahey, Schaughency, Hynd,

Carlson, & Nieves, 1987) as well as family social position and level of parental education (Barkley, DuPaul, & McMurray, 1990). Results from the DSM-IV field trials for ADHD revealed that a significantly greater percentage of the children and adolescents who qualified for a diagnosis of ADD/WO were female when compared to the percentage of females in the ADD/H group (Lahey et al., 1994). This finding is consistent with what was reported by Szatmari et al. (1988), but other researchers have not identified any gender differences (Barkley et al., 1990; Lahey et al., 1987; Morgan et al., 1996). Similarly, Lahey et al. (1987; 1994) reported that the ADD/H subjects in their samples were significantly older than the ADD/WO subjects, while other studies that examined the age of their samples reported no differences in this regard (Barkley et al., 1990; Morgan et al., 1996). These discrepancies in findings with respect to both age and gender can likely be attributed to the sample sizes utilized in the various studies. Most notably, both Lahey et al. (1994) and Szatmari et al. (1988) utilized relatively large sample sizes (i.e., 380 and larger) while the remaining studies that reported no gender differences and those that failed to identify any age difference recruited smaller samples for experimental purposes (i.e., less than 90). As such there appears to be some evidence to indicate a higher proportion of females and an older age at diagnosis in ADD/WO subjects than in their ADD/H counterparts.

Behavioral Characteristics

On the basis of self-report measures and rating scales completed by parents, teachers, and peers, ADD/H children have been described as more hyperactive and aggressive (Dykman & Ackerman, 1991; Edelbrock, Costello, & Kessler, 1984) and likely to receive a diagnosis of conduct disorder (Hynd et al., 1991), more impulsive (Lahey, Schaughency, Frame, & Strauss, 1985; Lahey et al., 1987; Stanford & Hynd, 1994), more likely to exhibit antisocial behavior (Berry, Shaywitz, & Shaywitz, 1985; King & Young, 1982; Lahey et al., 1987), more irresponsible, sloppy and disinhibited (Lahey et al., 1985), more disruptive (Baumgaertel et al., 1995; Stanford & Hynd, 1994), and more unpopular with peers (Edelbrock et al., 1984; Lahey, Schaughency, Strauss, & Frame, 1984). In contrast, ADD/WO children are reported to be more sluggish and day dreamy (Barkley et al., 1990; Lahey et al., 1985; Lahey et al., 1987), shy and socially withdrawn (Edelbrock et al., 1984; Lahey et al., 1984), and disorganized (Stanford & Hynd, 1994) than their ADD/H counterparts. Lahey et al. (1994) reported that ADD/WO subjects received lower ratings of global impairment than their ADD/H counterparts. However, both groups in their study received comparable ratings from their parents and teachers with respect to the severity of academic difficulties and the groups did not differ from one another on a measure of teacher rated social acceptance.

Rubinstein and Brown (1984) did not find ADD/H and ADD/WO children to differ on parent and teacher rating scales of inattention, impulsivity or overactivity, while Cantwell & Baker (1992) found that they differed only with respect to

overactivity, but not inattention or impulsivity. Barkley et al. (1990) found that the activity level of the two groups as measured by an actometer did not differ, and no difference was found in the number of offenses they committed as adolescents (Zagar, Arbit, Hughes, Busell, & Busch, 1989). Furthermore, both groups have been found to be similar with respect to ratings of peer status (Carlson, Lahey, Frame, Walker, & Hynd, 1987; King & Young, 1982), and behavior during a restricted academic situation (Barkley, DuPaul, & McMurray, 1991).

Although there does appear to be at least some evidence to suggest that ADD/H and ADD/WO are different with respect to their behavioral characteristics, establishing a distinction between two suspected groups on this basis does not meet the criteria for acceptable external validity. As Lorys, Hynd, & Lahey (1990) have suggested, "somewhat circular reasoning characterizes this literature in that only through behavioral measures can these subtypes be significantly and consistently differentiated, and behavioral measures are the means by which the subtypes were initially diagnosed" (p.132). Other differences that are independent of the original diagnosis must be identified to adequately establish the external validity of ADD/WO as a distinct entity.

Family History and Psychiatric Comorbidity

With respect to perinatal factors, Frank and Ben-Nun (1988) reported a significantly higher incidence of prenatal, perinatal, and neonatal abnormalities for the ADD/H group. McIntosh, Mulkins, & Dean (1995) found that while the number

of maternal perinatal risk factors was higher for ADHD subjects as a whole compared to controls, there were only minor differences between the ADD/WO and ADD/H subjects. Barkley et al. (1990) did not find any differences between ADD/H and ADD/WO children on reported perinatal complications, maternal health, or prior number of pregnancies or miscarriages.

The research literature on familial patterns of psychiatric illness and comorbid diagnoses does lend some support to the distinction between these two groups. It has been suggested that a diagnosis of ADD/H is associated with a family history of ADD/H, substance abuse, and aggression, while ADD/WO children are more likely to have a family history of anxiety and learning disorders (Barkley et al., 1990), and are more likely to receive a codiagnosis of a learning disorder (Hynd et al., 1991; Morgan et al., 1996) or an anxiety or affective disorder themselves (Lahey et al., 1987). Cantwell & Baker (1992) reported that family discord and maternal psychiatric illness were more prevalent in a group of ADD/H children, but the rates of depressive and anxious symptoms were found to be similar in their sample ADD/H and ADD/WO children.

Cantwell and Baker (1989) examined the stability of childhood psychiatric diagnoses and found that while ADD/H has good predictive validity, ADD/WO does not. Four years after the initial diagnosis, 80% of the ADD/H group in their sample received the same diagnosis once again while none of the ADD/WO group were diagnosed as such at follow-up. In fact 80% of the ADD/WO subjects received a diagnosis of ADD/H at follow-up, which prompted the authors to question the

validity of ADD/WO as a distinct syndrome. Maurer and Stewart (1980) reached the same conclusion based on the observation that most of the ADD/WO subjects in their sample qualified for additional psychiatric diagnoses. It may be that a variety of disorders, including ADD/H, are incorrectly diagnosed as ADD/WO since many of them have features that are similar to those associated with ADD/WO (e.g., inability to concentrate, easily distracted, socially withdrawn). However, once the full syndrome is developed, or more comprehensive assessment procedures are employed, the diagnosis of ADD/WO is replaced with a more appropriate one.

Test Performance

A number of studies have reported on the measured intelligence of ADD/H and ADD/WO samples. Barkley et al. (1991) found that the ADD/WO children in their samples had lower IQ's than their ADD/H counterparts, while Carlson, Lahey, and Neeper (1986) found just the opposite. However, the majority of studies reporting IQ data did not find any significant differences between these two groups (Ackerman, Anhalt, Dykman, & Holcomb, 1986; Barkley et al., 1990; Barkley, Grodzinsky, & DuPaul, 1992; Berry et al., 1985; Frank & Ben-Nun, 1988; Hynd et al., 1991; Morgan et al., 1996; Zagar et al., 1989).

Similar results have been reported with respect to academic achievement. Hynd et al. (1991) found that ADD/WO children scored lower than those diagnosed as ADD/H on a test of mathematics ability, but the two groups were not significantly different on measures of reading and spelling ability. A number of other studies that

examined this issue failed to detect any differences on tests of reading, spelling, or mathematics skills (Barkley et al., 1990; Carlson et al., 1986; Dykman & Ackerman, 1991; Morgan et al, 1996; Rubinstein & Brown 1984; Zagar et al., 1989). Taken together the results of these studies suggest that any observed differences in IQ or tests of academic achievement likely reflect random variance and/or a referral bias rather than a true difference between these populations.

ADD/H and ADD/WO subjects have also been compared on a wide variety of laboratory and neurocognitive measures. Attempts to distinguish the two groups on the Children's Revision of the Luria-Nebraska Neuropsychological Battery (Lorys et al., 1990; Schaughency, Lahey et al., 1989), Kagan's Matching Familiar Figures Test (Barkley et al., 1990; Barkley et al., 1991; Carlson et al., 1986; Rubinstein & Brown, 1984), the Stroop Color-Word Test (Barkley et al., 1992; Carlson et al., 1986), and several measures of effortful processing (Ackerman et al., 1986) have not been successful. Braun (1992) did not find any differences on the Wisconsin Card Sorting Test or on cancellation and coding tasks. Performance on a rapid naming task has been found to be similar in one study (Carlson et al., 1986), but ADD/H subjects were reported to exhibit superior performance on this task in another study (Hynd & Lorys et al., 1991). The two groups have also not been found to perform differently on measures of visual-motor integration (Zagar et al., 1989), language functioning, or visual attention span (Carlson et al., 1986).

Several versions of a continuous performance test have also been employed in comparing these two groups. Most of the studies identified in the literature found

that ADD/H and ADD/WO children performed similarly on these tasks with respect to the number of errors of omission and commission (Barkley et al., 1990; Barkley et al., 1992; Braun, 1992; Dykman & Ackerman, 1991; Holcomb, Ackerman, & Dykman, 1985; Holcomb, Ackerman, & Dykman, 1986; Rubinstein & Brown, 1984). However, Barkley et al. (1991) reported that their ADD/H subjects made significantly more omission and commission errors than their ADD/WO subjects. In contrast, Trommer, Hoeppner, Lorber and Armstrong (1988) found that while ADD/H children made the highest number of commission errors, the ADD/WO children made significantly more omissions but then improved their error rate drastically on a second trial while the ADD/H subjects' performance actually deteriorated over time. Studies examining reaction time have shown that while controls seem to have faster reaction times than ADHD subjects, this variable did not discriminate between groups of ADD/H and ADD/WO children (Dykman, Ackerman, & Oglesby, 1992; Holcomb et al., 1985, 1986). Similar findings were reported by Hynd et al. (1989) who also found that while ADD/H children in this study proved to have greater within-subject variability (with respect to reaction time) than controls, they were not significantly different than the ADD/WO group in this regard.

Frank and Ben-Nun (1988) compared ADD/H and ADD/WO children on a structured neurological examination as well as a variety of cognitive tests. They found that the performance of ADD/H children was inferior to that of ADD/WO children on tasks of visual sequential memory, auditory association , and writing, but the scores of the two groups on nine other cognitive measures did not differ.

Although both groups exhibited neurological abnormalities, the ADD/H group exhibited a significantly greater degree of dysfunction. Using a battery of sensorimotor variables, Hern and Hynd (1992) found that the ADD/WO children in their study were no more likely than controls to exhibit soft neurological signs, but ADD/H children, particularly those older than eight years of age, exhibited more of these signs than either ADD/WO children or controls. The neurological findings of the Frank and Ben-Nun (1988) study must be interpreted cautiously since the process of conducting neurological examinations is an extremely subjective task, and unlike the examiners in the Hern and Hynd (1992) study, it does not appear that the researchers were blind to the group membership of the subjects.

Treatment Response

Both ADD/H and ADD/WO children have been found to respond favorably to stimulant medication (Barkley et al., 1991; Dykman & Ackerman, 1991; Famularo & Fenton, 1987; Ullmann & Sleator, 1985). However there has been some suggestion that there may be minimal differences in the response profiles of the two groups. On the basis of clinical judgment, Barkley et al. (1991) suggested that children diagnosed with ADD/H were more likely to be positive responders and to require higher doses for optimum results than children diagnosed as ADD/WO. On a similar note, Dykman and Ackerman (1991) found that while there was no difference in the amount of improvement on laboratory measures associated with the use of stimulant medication, the ADD/H subjects were rated as significantly more improved on the

basis of teacher rating scales. This is likely because the disruptive behavior of ADD/H children is often more observable and disconcerting to teachers than the day dreamy and withdrawn behavior exhibited by children with ADD/WO.

Physiological and Neuroanatomical Correlates

As Fletcher et al.(1991) have suggested, the external validity of a disorder may be appropriately established by demonstrating that it can somehow be distinguished on variables that are from a different measurement domain than the ones used to make the initial diagnosis. Given the presumed neurological basis for the attention deficit disorders, it would seem logical to consider the physiological aspects of ADD/WO as compared to ADD/H in order to evaluate its external validity. In a unique study, Hole et al. (1988) employed a procedure (G-25 gel filtration) for analyzing the concentrations of peptide-containing complexes in urine samples of control children and those who were identified as either ADD/H or ADD/WO. Three different patterns of late peak concentrations emerged from their analyses, one corresponding to each of the experimental groups. The control subjects exhibited patterns that were different from those receiving a clinical diagnosis, while all of the subjects who exhibited a pattern characterized by increased amounts of benzoic acid-glycoprotein-peptide complexes fit the criteria for ADD/H. A third pattern showing reduced amounts of uric acid complexes also emerged. Ninety-one percent of this group fit the criteria for ADD/WO, while the remainder were classified as ADD/H. Although the significance of these findings is unclear, the researchers noted that

peptides function in the brain as neurotransmitters, neuromodulators and hormones, and they hypothesized that "in these syndromes, there may be an alteration (decrease or increase) in peptidase levels due either to brain damage or to other changes in brain function, or to genetic causes" (p. 210). In any case, these findings provide some support for the external validity of ADD/WO and may eventually prove to be useful diagnostically.

Dykman et al. (1992) examined the heart rate reactivity of children classified as ADD/WO, ADD/H, and ADD/H with aggression. They found that the subjects in the ADD/WO group had lower heart rates than the ADD/H or ADD/H with aggression groups, but mixed results were obtained when the sample was analyzed according to gender. Compared to the hyperactive boys, those with ADD/WO demonstrated more marked acceleration and deceleration of the heart beat in response to warning signals, but this pattern was not found for girls.

Holcomb et al. (1985) examined the event-related potentials (ERP) of ADD/H, ADD/WO, reading disabled, and control children while they were completing a visual continuous performance test. They found that both the amplitude and the latency of the P3 wave distinguished between the control and the clinical groups, but these variables did not differentiate between the ADD/H, ADD/WO, or reading disabled groups. In a similar study (Holcomb et al., 1986) the ERP components of the same subjects were evaluated during the completion of an auditory continuous performance test. Once again, several variables differentiated between the control and clinical subjects. In addition, while mean amplitude of the P_2 wave

was larger for ADD/H group than for the ADD/WO group at one site (CZ), these two groups did not differ on any of the other approximately 150 variables.

Lahat, Avita, Barr, Berkovitch, Arlazoroff and Aladjem (1995) compared ADD/WO, ADD/H and control children using brainstem auditory evoked potentials (BAEPs). No significant differences were found between the two clinical groups, but both were found to differ significantly from the control group. Specifically, the ADD/WO and ADD/H subjects exhibited longer latencies and brain transmission times when compared to the control subjects.

The existing literature on the EEG characteristics of children with attentional disturbances is difficult to interpret because of the variety of labels and different mixtures of disordered children that have been employed over the years. In addition, the manner in which results are reported (e.g., absolute versus relative measures) and the varying activities the subjects engaged in while the data was being collected adds to the problem of making comparisons across different studies. Nevertheless, the majority of the research findings suggest that when compared to normal controls children who are often described as hyperactive typically exhibit excessive slow wave activity (typically in the theta band) and/or a concomitant decrease in fast wave (primarily alpha and beta) activity (Callaway, Halliday, & Naylor, 1983; Capute, Niedermeyer, & Richardson, 1968; Dykman, Holcomb, Oglesby, & Ackerman, 1982; Gillberg, Matousek, Petersen, & Rasmussen, 1984; Harper, Deering, Cavernos-Gonzales, McNeil, & Ulman, 1996; Janzen & Fitzsimmons, 1995; Klingerfuss, Lange, Weinberg, & O'Leary, 1965; Matsuura et al., 1993). Such

findings are consistent with a hypoarousal hypothesis of hyperactivity (Klove, 1989; Zentall, 1975; Zentall & Zentall, 1983) and provide evidence that ADHD is a neurophysiological disorder.

Some of the research results reported by Satterfield and his colleagues differ from those of the aforementioned studies. For instance, Satterfield, Schell, Backs, & Hidaka (1984) found that younger hyperactive children (under seven and one half years old) displayed significantly lower EEG power than normal controls of the same age, while older hyperactive subjects (over seven and one half years of age) tended to exhibit higher power than age matched controls across all EEG frequency bands. In another study Satterfield & Schell (1984) compared the EEG characteristics of delinquent hyperactive children, nondelinquent hyperactive children, and normal control children while they viewed a videotaped cartoon with distracting auditory clicks from another source that they were instructed to ignore. None of the subjects in this study displayed symptoms of inattention without concomitant hyperactivity. The delinquent hyperactive group did not differ from the normal subjects in terms of EEG power. However, the nondelinquent hyperactive group (who were likely equivalent to ADD/H as defined in the present context) were found to have higher total power when compared to the control group. In addition, the nondelinquent hyperactive subjects exhibited higher absolute power and higher relative power in the alpha and beta2 bands, and lower relative power in the theta band when compared to the controls. These latter findings are virtually opposite to those reported by most other researchers.

There is also some evidence to suggest that the presence of subtle EEG abnormalities (i.e., excessive slow wave activity, higher mean EEG amplitudes, and epileptiform discharges) in hyperactive children is a good predictor of response to stimulant medication (Satterfield, 1973; Satterfield, Cantwell, & Satterfield, 1974). Indeed, Craggs, Wright, & Werry (1980) as well as Shetty (1971) found that the administration of stimulant medication is associated with an increase in the alpha band while Caresia et al. (1984) found a similar effect in the beta1 band (13 - 20 Hz).

Three studies have examined the differences in on-task EEG between ADD/WO and control subjects. Mann, Lubar, Zimmerman, Miller, and Muenchen (1992) found that ADD/WO children exhibited higher overall amplitude, more theta in frontal and central regions, and decreased beta in temporal and parietal regions. These differences were most significant during reading and drawing tasks. In a similar study Janzen (1992) compared ADD/WO and control children on numerous EEG variables while they were completing a variety of tasks. The ADD/WO group displayed higher amplitude in all sites and for tasks, more relative power in the theta band, and less relative power in the SMR and beta bands than controls. The differences between the two groups were generally larger during the on-task conditions, and theta differences were most pronounced in the parietal sites. Finally, it was noted that the control subjects suppressed alpha to a greater extent than did the ADD/WO subjects when they shifted from a resting (eyes open) to an on-task condition. Changes in other frequencies bands were similar between the two groups. Janzen, Graap, Stephanson, Marshall, & Fitzsimmons (1995) also found that the

theta amplitudes of a group of ADD/WO boys were significantly higher than those displayed by controls. This finding held true for all five sites that were examined while the subjects were reading, drawing, and during a baseline condition (eyes open). In addition, it was found that the ADD/WO group exhibited higher ratios of slow wave to fast wave activity (i.e., ratios of theta to SMR and theta to beta) than did the control group, particularly in the parietal regions during on task conditions.

Based on the aforementioned studies there is some evidence to suggest that children diagnosed as ADD/WO may exhibit EEG patterns that are similar to those exhibited by ADD/H children (i.e., excessive slow wave activity in the theta band). However, a comprehensive search of the literature only identified one study that addressed this issue. Grunewald-Zuberbier, Grunewald, & Rasche (1975) compared EEG recordings of behaviorally disturbed hyperactive and behaviorally disturbed nonhyperactive children during the completion of a reaction time task. Although there is no guarantee these children would be classified as ADD/H and ADD/WO respectively by current diagnostic criteria, the groups were formed by selecting two extreme groups: those who exhibited extreme motor restlessness and those who exhibited a low level of motor activity. Furthermore, the hyperactive group was rated as more impulsive and more distractible than the nonhyperactive group. As such, the subjects exhibited at least some of the characteristics typically associated with ADD/H and ADD/WO. Recordings were made from three sites over the left hemisphere (O1, P3, C3) while the subjects were resting with eyes open and eyes closed as well as during the on-task condition. The researchers found that the

hyperactive group exhibited higher alpha and beta amplitudes, a greater amount of alpha waves, and a smaller amount of beta waves than the nonhyperactive group. Although these differences rarely reached the level of significance, the authors interpreted the findings as suggesting that the hyperactive subjects were underaroused as compared to the nonhyperactive subjects. However, it is important to note that the population of children from which their sample was selected were all designated as behaviorally disturbed, and consequently the difference between their respective levels of hyperactivity and impulsivity may not have been nearly as extreme as what is typically observed between children who are currently being diagnosed as ADD/WO and ADD/H. Furthermore, the fact that the nonhyperactive children selected for this study were also classified as behaviorally disturbed suggests that they may have qualified for a diagnosis of Oppositional Defiant Disorder or Conduct Disorder according to DSM-IV criteria. Nevertheless, at the present time this study provides the only direct comparison of EEG characteristics between children who exhibit contrasting levels of hyperactivity.

Judging from the limited evidence that is currently available it appears that ADD/H and ADD/WO subjects may both exhibit a pattern of increased slow wave activity and decreased fast wave activity. However, this has not been investigated directly and it is possible that these two groups may show a different pattern of cerebral localization and change in EEG characteristics while completing different tasks.

There appears to be some convergence with respect to speculation concerning the probable neuroanatomical substrates involved in ADD/H and ADD/WO; the former being associated with the anterior or prefrontal region, and the latter being associated with the parietal/temporal regions (Barkley et al., 1991; Schaughency & Hynd, 1989; Voeller, 1991). Indeed, research on ADHD subjects has strongly implicated the anterior regions, particularly the right hemisphere (Brumback & Stanton, 1982; Carter, Krener, Chaderjian, Northcutt, & Wolfe, 1995; Hynd et al., 1993; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Lou, Henriksen & Bruhn, 1984; Lou, Henriksen, Bruhn, Borner, & Nielsen, 1989; Zametkin et al., 1990), but none of these studies included any subjects classified as ADD/WO.

Summary of the Relevant Research

From the evidence that has been accumulated thus far, it must be said that the argument for classifying ADD/H and ADD/WO as two distinct syndromes, or even two subtypes of the same disorder, is far from convincing. There has been an over reliance on the use of behavior rating scales to demonstrate the differences between these two groups of children, and there is even conflicting evidence with respect to the levels of overactivity they exhibit. Reported differences in comorbid diagnoses and familial patterns of psychiatric disturbance can be interpreted as evidence of the instability of ADD/WO, arguing against its status as a distinct syndrome. The research comparing ADD/H and ADD/WO children on variables which are appropriate for establishing external validity, such as psychological test performance,

has been largely unsuccessful in identifying consistent differences. Generally speaking there does appear to be a common trend emerging from many of the research studies suggesting that ADD/H subjects are more impaired than ADD/WO subjects, who are in turn more impaired than control subjects on a variety of tests and laboratory tasks. However, while such a trend can be interpreted as supporting the hypothesis that these are indeed different syndromes, it is just as plausible to suggest that the difference between ADD/H and ADD/WO is more a matter of quantity rather than quality (i.e., the same entity that is present to a different degree). Although there is some evidence to suggest that ADD/H subjects exhibit more soft neurological signs and respond better to higher doses of stimulant medication than ADD/WO subjects, it may be argued that these differences reflect the severity of the presenting symptoms rather than a qualitative difference in the nature of these two classifications. More definitive results have emerged from studies investigating physiological and neuroanatomical correlates, but research in this area is still in an infancy stage and additional studies are needed to substantiate initial findings.

Many of the inconsistencies reported in the literature may be a result of differences in sample selection. For instance, a number of the studies which reported increased aggression and antisocial behavior in ADD/H children did not exclude subjects who were diagnosed with concomitant conduct disorder (Dykman & Ackerman, 1991; Edelbrock et al., 1984; Lahey et al., 1987). In addition, the method of separating ADD/H and ADD/WO subjects was inadequate in a number of studies (e.g., Barkley et al., 1991, 1990) since the difference between the groups on

behavioral measures of overactivity and inattention were relatively small. Finally, some of the studies employed a clinic referred population while others sampled from a community population by using teacher ratings of students to formulate the two groups. A study by Epstein et al. (1991) suggests that a referral bias may exist whereby children referred to psychiatrists exhibit more extreme behaviors than those referred to psychologists, pediatricians, and child neurologists. These observations argue strongly for careful screening and diagnosis of experimental groups to ensure that the subjects are both representative of their supposed diagnostic categories and without coexisting disorders that may bias the results.

It seems reasonable to expect that such disparate behavioral characteristics as are reported in the literature for ADD/H and ADD/WO children may be associated with different etiologic factors, and consequently may require differential methods of treatment. There appears to be a growing consensus that in fact a distinction of this sort may be clinically meaningful. As Barkley (1990) has suggested, "the evidence available to date compels us to begin considering ADD/+H and ADD/-H as separate and unique childhood disorders" (p.91). However, differences on variables that are suitable for establishing external validity have not yet been consistently demonstrated. Dykman & Ackerman (1993) have suggested that research attempting to validate subtypes of ADHD should employ subjects who display extreme behavioral scores, select laboratory tasks that are related to the behavioral traits which differentiate between the groups, and measure physiological processes during the completion of these tasks.

Statement of the Research Problem

The purpose of the present study was to examine the external validity of ADD/WO as a diagnostic category by comparing a carefully selected group of children who met the DSM-IV criteria for ADHD, Predominantly Inattentive Type, with a group of ADD/H children who met the criteria for ADHD, Combined Type. Given that these groups have never been directly compared on EEG variables, this research was conceptualized as exploratory and as such the primary aim was to identify suspected differences or trends between the groups to provide direction for future investigations. In keeping with the suggestions of Dykman & Ackerman (1993), psychophysiological (EEG) data were collected while the subjects completed a computerized task (Test of Variables of Attention: TOVA) that measures a variety of constructs associated with attention and impulsivity, and an effort was made to select participants who differed substantially with respect to their behavioral characteristics (i.e., the presence or absence of hyperactivity and impulsivity). In addition, every attempt was made to ensure that the results would not be confounded by the presence of any concomitant diagnoses in the research sample.

Footnote: A version of this chapter has been published. Stewart 1994. Canadian Journal of School Psychology. 10: 15-25.

CHAPTER III

METHOD

Subjects

Criteria for considering a child's inclusion in the study were as follows: (1) male between 10 and 12 years of age; (2) right handed; (3) possessing average intelligence or higher; (4) no evidence of a specific learning disability; (5) able to be completely free of any medication used to treat the symptoms of ADHD on the day the EEG evaluation was completed. The subjects for the study were accessed from three primary sources. Approximately half of the ADD/H and ADD/WO subjects had previously been evaluated through the Education Clinic, Department of Educational Psychology, at the University of Alberta. Males within the appropriate age range who had difficulties with inattention and/or hyperactivity were identified from the Education Clinic files and the parents were contacted by telephone and invited to participate in the study. The remainder of the ADD/H and ADD/WO subjects were accessed through The Attentional Disorders Association (TADA). The purpose and design of the research study was presented at a TADA meeting attended by approximately 200 individuals, and parents of children who appeared to meet the criteria for inclusion in the study were invited to contact the researcher for more information. The control sample consisted of children who attended either a local school or church congregation.

Selection of the subjects for the present study was completed in three phases. During the first phase of the selection process the parents of potential subjects were

asked to complete two behavior rating scales as well as a general information and history form (see Appendix A). The first rating scale was developed specifically for the purposes of the present study and was fashioned after the SNAP rating scale (Swanson, Nolan, & Pelham, 1981). The SNAP consists primarily of the DSM-III criteria for Attention Deficit Disorder whereas the rating scale used in the present study contained the 18 items used to diagnose ADHD according to DSM-IV criteria (see Appendix B). Parents were instructed to indicate the degree to which their child exhibited these symptoms while he was not taking any medication for ADHD by endorsing one of the following choices: *not at all*, *just a little*, *pretty much*, or *very much*. From this point on this instrument will be referred to as the DSM-IV checklist. The appropriate form (6 to 11 years, or 12 to 18 years, depending on the age of the child) of the Parent Report Scale of the Behavior Assessment System for Children (BASC; American Guidance Service, 1992) was also completed as a means of providing general information regarding each subject's emotional and behavioral characteristics. In order to maintain uniformity, only the ratings provided by mothers on the DSM-IV checklist and the BASC were utilized in the present study. An attempt was also made to obtain teacher ratings of the presence of ADHD symptoms for each subject during the selection process. However, this proved to be quite problematic since many of the teachers had never observed the children while they were off medication. In addition, some of the subjects were accepted into the study over the summer months when teacher input was not available. Consequently a decision was made to identify potential ADHD subjects by relying exclusively on

information provided by parents on the DSM-IV checklist, the general information and history form, and previous diagnoses that been provided by mental health and medical professionals.

Children who were left hand dominant, those who were taking a long-acting medication as a treatment for ADHD, and those with a history of significant head injury or serious neurological disorder were automatically excluded from the study. Potential subjects for the ADD/H and ADD/WO groups were then identified based on their scores on the DSM-IV checklist. Those subjects who received ratings of either *pretty much* or *very much* on six or more of the inattention items but less than five of the hyperactivity-impulsivity items were classified as ADD/WO. Similarly, those who were rated as either *pretty much* or *very much* on six or more of the inattention items and six or more of the hyperactivity-impulsivity items were classified as ADD/H. This procedure was followed in order to ensure there would be a meaningful difference between the two clinical groups in terms of their levels of hyperactivity and impulsivity. None of the members of the control group received ratings of *pretty much* or *very much* on more than four of either the inattention or the hyperactivity-impulsivity items. For the purposes of the statistical analysis values were assinged to reflect the presence or absence of each of the 18 symptoms on the DSM-IV checklist. One point was assigned for a rating of *very much* or *pretty much*, while a rating of *just a little* or *not at all.* received zero points.

Subjects who did not qualify for any of the groups according to the aforementioned criteria were excluded from the study. Children who had previously

been diagnosed with Conduct Disorder were also excluded. However, as is often the case with children who have ADHD, there were a number of subjects who would likely have met the DSM-IV criteria for Oppositional Defiant Disorder.

During the second phase of the selection process all potential subjects were administered the Wechsler Intelligence Scale for Children - Third Revision (WISC-III; Wechsler, 1991) and the Screening Form of the Wechsler Individual Achievement Test (WIAT; The Psychological Corporation, 1992). The testing was administered by the primary researcher or by individuals who had completed Master's level training and supervision in the administration of psychological and educational tests. For some subjects one or both of these instruments had been administered within one year of their inclusion in the study, and in these cases the recent test results were obtained and retesting was not completed. All subjects included in the study had a Full Scale Intelligence Quotient that fell at or above 90. In addition, the Reading, Spelling, and Mathematics Reasoning scores from the WIAT were above 85 for all subjects (i.e., within one standard deviation of the mean or higher). Finally, all subjects displayed a consistent preference for using their right hand on pencil and paper tasks. Upon completion of the data collection the parents of the children participating in the research project received a written summary of their child's psychoeducational assessment results. A sample report is presented in Appendix C.

A large number of potential subjects were excluded from the study because they were being treated for ADHD with long-acting medications. It is generally

accepted that it is necessary to wait a minimum of five half-lives before it can be reasonably assured that psychotropic medications no longer have an effect on the central nervous system (L. Pagliaro, personal communication). Whereas methylphenidate has an estimated half-life of two to four hours, the half-life of other medications commonly used to treat ADHD (e.g., dextroamphetamine, pemoline, and desipramine) can range from 11 to 36 hours (Maxmen, 1991). In order to ensure that the final sample consisted of subjects who were not under the influence of any medication used to treat ADHD, only those who were not taking any medication at the time of the EEG evaluation or only taking methylphenidate were accepted. Furthermore, all of the subjects in the latter group were required to refrain from taking their methylphenidate for a minimum of 24 hours (i.e., more than five half-lives) prior to the collection of the EEG data.

The final sample consisted of 27 right handed male subjects between the ages of 10 and 12. Previous research has shown that the EEG characteristics of boys between the ages of 9 and 13 are stable for up to three years (Fein, Galin, Yingling, Johnstone, & Nelson, 1984). Nine boys served in each of the ADD/H, ADD/WO and control groups. The mean age of the control group on the date of the EEG evaluation was 11.66 years while the mean of the ADD/H and ADD/WO groups were 10.85 and 11.58 years respectively. The difference between the groups with respect to their ages was not significant, $F(2, 24) = 2.29, p = .122$. Participation in the study was completely voluntary and both the child and one of his parents were required to sign an information and consent form (see Appendix D).

Six of the nine subjects in the ADD/H group had previously been diagnosed with ADHD: five by a medical practitioner and one by a psychologist. Only four of these specified that the diagnosis was ADHD, Combined Type. Five of the subjects in the ADD/H group were being treated with methylphenidate while another had been given a prescription for this medication which was never filled. One subject had been prescribed dextroamphetamine and desipramine, but had discontinued these medications over the summer months during which time the EEG evaluation was completed. The remaining three subjects in the ADD/H group had previously undergone psychological assessments which identified problems with both inattention and hyperactivity, but no formal diagnosis was provided. Seven of the nine subjects in the ADD/WO group had previously been diagnosed with ADHD: five by medical practitioners and two by psychologists. In all but one of these instances a diagnosis of ADHD, Predominantly Inattentive Type, was specified. Only three of the ADD/WO subjects were being treated with medication. Two were taking methylphenidate and one had been prescribed pemoline but stopped taking this medication approximately one month prior to the EEG evaluation. Previous psychological assessments on the remaining two subjects included in the ADD/WO group had identified problems with inattention, but once again no formal diagnosis was offered. None of the subjects in the control group exhibited any behavioral or academic difficulties according to parent's report. Furthermore, none of them had any chronic health problems nor were they taking any prescription medication at the time of the EEG evaluation.

Apparatus

Monopolar recording of the EEG was performed using the Neurosearch-24 system developed by the Lexicor Corporation (Lexicor Medical Technology, 1990). A nylon electrocap with twenty electrodes positioned according to the International 10-20 system (Jasper, 1958) was used to collect the EEG data. (See Appendix E for an illustration of the International 10-20 system.)

Several studies have investigated the reliability of quantitative EEG data. Test-retest reliabilities above .71 for absolute power over one to three years have been reported for the theta, beta and high beta bands, while the delta band reliability coefficients all fell above .54 (Fein et al., 1984). Based on one to two hour intervals Prichep, John, Ahn, & Kaye (1983) obtained an average test-retest reliability of .83 for the delta, theta, alpha and beta bands across eight different sites (F3, F4, C3, C4, P3, P4, O1, O2) during an eyes closed condition. Furthermore, none of the individual reliability coefficients for any site/bandwidth combinations fell below .71. Janzen, Norman, Grapp, & Fitzsimmons (in press) evaluated the test-retest reliability of quantitative EEG using the same equipment that was employed in the present study. EEG readings of normal 10 to 12 year old boys were obtained during eyes open, eyes closed, reading silently, and drawing conditions. Data were collected on three separate occasions; pre-test, eight days and six months later. Average test-retest reliabilities over this period of time ranged from .62 to .89 for theta, .47 to .90 for alpha, .88 to .97 for SMR, and .76 to .93 for beta.

The Test of Variables of Attention (TOVA) is a computerized continuous performance test which utilizes simple geometric stimuli and requires no language skill or right-left discrimination (Greenberg, 1991). The subject is presented with a square on the computer screen that either has a hole near the top edge or near the bottom edge. The presentation rate is once every two seconds and the stimulus is visible for 100 milliseconds. The subject is instructed to press a microswitch every time there is a hole near the top of the square (target) and not to respond when there is a hole near the bottom of the square (nontarget). The entire test takes approximately 23 minutes to administer. Following a brief practice session the TOVA is split into two 11 minute halves. During the first half (TOVA1) the target is randomly presented once for every three and one half nontargets (infrequent condition). During the second half (TOVA2) the ratio is reversed so that the target is presented three and one half times for every presentation of the nontarget (frequent condition). Thus, boredom may become a major factor during the first half of the test, while inhibition of a response as well as boredom may be major factors during the second half of the test.

The four primary variables that are scored from the TOVA are: errors of omission, which are though to reflect inattention; errors of commission, which are interpreted as a measure of impulsivity; mean correct response times, believed to be indicative of processing and response time; and variability, which is a measure of consistency derived from the standard deviations of the response times. Errors of omission and errors of commission are reported in terms of the total percentage of

errors that were made while response time and variability are measured in milliseconds. Scores for each of these variables are available for each quarter and each half of the test, as well as the total test (only the total test scores were analyzed in the present study).

Three additional TOVA variables are also available, only one of which is pertinent to the present study. Anticipatory responses (defined as responses before and less than 200 milliseconds after the presentation of the stimulus) indicate that the examinee was guessing and are used as a measure of reliability. When the percent of anticipatory responses in any one quarter is 10 % or greater the results must be interpreted with caution. When this situation occurs in more than one quarter, the results are considered unreliable. An additional check on the reliability of an examinee's score can be obtained from the percentage of commission errors. When this type of error is equal to or greater than 60% in any one quarter, one must be cautious in interpreting the data. However, once again, as long as this situation does not occur in more than one quarter the results are considered to be interpretable.

Continuous performance tests such as the TOVA are typically conceptualized as a measure of sustained attention or vigilance (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). The TOVA has been shown to be sensitive to the effects of caffeine on attention (Bernstein et al., 1994), and it has been used to demonstrate the effectiveness of neurofeedback training on ADHD children (Lubar, Swartwood, Swartwood, & O'Donnell, 1995). Reader, Harris, Schuerholz, & Denckla (1994) examined the performance of ADHD children on the TOVA. The subjects they

employed in their study all exhibited symptoms of hyperactivity and impulsivity, and although the exact diagnosis was not specified, based on the description of the participants it is likely that they would have qualified for a diagnosis of ADHD, Combined Type according to DSM-IV criteria. The ADHD subjects made significantly more errors of omission and had slower and more variable reaction times when compared to the normative data available for the TOVA (Greenberg & Waldman, 1993). These results suggest that at least three of the four primary TOVA variables may be sensitive to the types of deficits displayed by ADHD children.

Hassan (1995) examined the correlations between the four primary TOVA scores and EEG variables derived from nine sites (C3, C4, CZ, FZ, O1, O2, P3, P4, PZ). The highest correlations were between alpha amplitude and errors of omission, errors of commission, and response time variance. These findings were most prominent in the occipital and parietal sites. However, only the first ten minutes of the TOVA were used, and it is quite possible that other significant correlations may have emerged if the second half of the TOVA was included since it appears to be more susceptible to impulsivity and deficits in vigilance.

Although there is as yet no evidence to indicate that scores on the TOVA can differentiate ADD/H and ADD/WO subjects, this issue has not been addressed directly. Furthermore, the electrocortical activity associated with performance on the TOVA may be different for the two subtypes. In other words, while both groups may obtain similar TOVA scores, they may do so for very different reasons. The TOVA was selected as a representative measure of attention and the ability to inhibit

responding. In addition, it requires very little movement (only the flexion of the thumb) and no visual scanning. In fact, the TOVA incorporates a focusing point to help examinees keep their eyes fixed on the middle of the computer screen. These characteristics are highly desirable in the present context as it is important to minimize the occurrence of movement artifact in the EEG record.

Procedure

The EEG recordings took place in a biofeedback training room at the University of Alberta between the hours of 9 a.m. and 3 p.m. All subjects either washed their hair prior to arriving for the recording session or had it washed and dried in the data collection room immediately before they were fitted with the electrocap. Each site was prepared using Electro-gel until all impedances measured below 5 ohms. A monopolar montage with linked ear reference was used for the recording and settings on the Neurosearch-24 were as follows: Sampling rate = 128 samples per second; Gain = 32000; High Pass Filter = 0.5 Hertz; Low Pass Filter = 32 Hertz. The EEG recordings were initially saved on a computer hard drive before being transferred to tape.

Prior to the data collection the subjects were allowed to observe their production of EEG waves as they were displayed on a computer screen. They were also given an opportunity to observe the production of unwanted artifact by creating muscle tension and moving their eyes, followed by a request to avoid this type of activity as much as possible during the data collection process. Each subject was

seated comfortably in a high back chair for the recording of the EEG data, which was collected under the following three conditions: resting with eyes open for five minutes, resting with eyes closed for five minutes, and during the completion of the TOVA.

During the data collection it was sometimes necessary to remind the subjects not to engage in activity that created unwanted muscle artifact (e.g., excessive eye blinks, jaw movement, shifting in the chair, moving feet, etc.). In general it was observed that the ADD/H subjects experienced the most difficulty in this regard, and consequently they received more reminders than subjects in the ADD/WO and control group. A short break of one or two minutes was taken between the recording of the eyes open, eyes closed, and TOVA conditions, but the entire TOVA was administered to each subject without interruption.

Data Analysis

A multivariate analysis of variance was used to compare the scores for the three groups on the BASC and the DSM-IV checklist, the total TOVA scores, the Full Scale IQ and Factor Index scores of the WISC-III, as well as the Reading, Spelling and Mathematical Reasoning scores from the WIAT. Post hoc comparisons were also conducted where appropriate.

The EEG records were visually inspected by an experienced EEG technician who was blind to the group membership of each subject. Any epochs containing muscle artifact due to tension, eye blinks or eye movements were discarded. For a

number of subjects some of the channels contained muscle artifact throughout the entire EEG record, particularly in the FP1, FP2, T3 and T4 locations. Consequently, only the following channels were considered during the artifacting process: FZ, F3, F4, CZ, C3, C4, PZ, P3, P4, O1, O2. All other channels (FP1, FP2, F7, F8, T3, T4, T5, and T6) were excluded from the analysis. The remaining data were then divided into six frequency bands: Delta, 1-4 Hz.; theta, 4-8 Hz.; alpha, 8-12 Hz.; sensory motor rhythm (SMR), 12-16 Hz.; beta1, 16-20 Hz.; and beta2, 20-24 Hz. For the purposes of the EEG recordings the TOVA was divided into two equal parts: The first 11 minutes of the test (infrequent condition) were designated as TOVA1 while the remaining 11 minutes (frequent condition) were designated as TOVA2. This division was necessitated by limitations of the computer system to process the large amount of data collected during the administration of the TOVA.

Given the exploratory nature of the present study it was deemed important to consider the entire spectrum of the EEG signal (i.e., all of the available bandwidths) and to include as many sites as possible. Most anatomical models of attention hypothesize that this process is subserved by many different cerebral structures (Colby, 1991; Posner & Petersen, 1990), particularly those in the right hemisphere (Heilman & Van Den Abell, 1980; Mesulam, 1981). Numerous research studies have supported the hypothesis of right hemisphere dysfunction in ADHD children (Brumback & Stanton, 1982; Cameron, et al., 1995; Hynd et al., 1990, Voeller & Heilman, 1988). However, Hynd et al. (1993) reported a smaller left caudate

nucleus in ADD/H subjects compared to normal subjects, and the results of a recent study by Branch, Cohen, & Hynd (1995) provided little support for the hypothesis that the right hemisphere is dominant for attention and concentration. Furthermore, it has been found that large portions of both cerebral hemispheres are noticeably activated during the completion of tasks with high attentional demands (Dujardin, Derambure, Defebvre, Bourriez, Jacquesson, & Guieu, 1993). Although the frontal lobes have been implicated as a probable region of dysfunction in ADHD subjects (Benson, 1991; Carter et al., 1995; Hynd et al., 1993; Hynd et al., 1990; Lou et al., 1984; Lou et al., 1989; Zametkin et al., 1990), it has also been hypothesized that dysfunction in the parietal lobes may underlie the type of attention problems observed in children with ADD/WO (Barkley et al., 1991; Schaughency & Hynd, 1989; Voeller, 1991). Furthermore, previous EEG research has identified the parietal sites as being the most useful in discriminating between ADHD subjects and normals (Janzen, 1992). Hassan (1995) also identified occipital and parietal sites as providing the highest correlations between the EEG and TOVA scores, and this might be expected given that the TOVA is essentially a visual task. Based on these findings and the wide variety of brain regions that have been implicated in ADHD, it seemed appropriate to include as many EEG sites as possible in the analysis.

The final selection of variables included in the analysis was based on the following rationale. In order to allow for a more comprehensive evaluation of the available data, all eleven of the sites considered in the artifacting process were also included in the statistical analysis (i.e., FZ, F3, F4, CZ, C3, C4, PZ, P3, P4, O1,

O2). Based on previous research findings which suggest that the differences between groups appear to be greatest during on-task conditions (Janzen, 1992; Janzen & Fitzsimmons, 1995; Mann et al., 1992), a decision was made to exclude the eyes open and eyes closed conditions, and to focus the data analysis exclusively on the TOVA1 and TOVA2 conditions. The only exception is that the eyes open condition was used as a baseline against which TOVA1 and TOVA2 values were compared. Although the eyes closed condition was not included in the data analysis, together with the eyes open condition it served to acclimate the subjects to the EEG recording procedures before the TOVA1 and TOVA2 conditions were presented. In addition, the increase in alpha activity that is typically evident when the eyes are closed was observed for each subject, indicating that the collection of the EEG data was proceeding according to expectations.

Quantitative analyses were used to determine the total power within each of the selected frequency bands for each of the eleven electrode sites and each of the three conditions. The Neurosearch-24 computer system automatically performs a fast fourier transformation on the data and provides values for the means (referred to as magnitude) and standard deviations of absolute power within each band. Magnitude, which is defined as the voltage of a wave measured peak to peak, is reported in microvolts (uV).

The EEG data were initially examined using an analysis of covariance design with the scores from the eyes open condition serving as the covariate. The primary reason for using this technique was to increase statistical power, thereby increasing

the likelihood that any appreciable differences between the three groups would be detected (Huck, Cormier & Bounds, 1974). Although it is almost always desirable to increase statistical power, this was deemed to be particularly important in the present study given the difficulty that was encountered in securing a sufficient number of subjects that met the strict criteria for inclusion, and consequently the relatively small sample size that was ultimately utilized.

In keeping with previous research, mean magnitude at each site constituted one of the variables included in the data analysis. However, given that within-subject variability on both the TOVA (Greenberg & Waldman, 1993) and on response time tasks (Hynd, 1989) has been found to differentiate between ADHD subjects and controls, the standard deviations for each variable associated with each individual subject's EEG record were also included in the analysis. A total of 132 variables (11 sites X 6 EEG bandwidths X 2 values) were calculated for each of the TOVA1 and TOVA2 conditions.

In an attempt to provide a more detailed examination of the data, change scores (defined as the change in each variable from the eyes open condition to the TOVA1 and TOVA2 conditions) were obtained for each group and compared using a series of one-way analyses of variance. The change scores were calculated by subtracting the eyes open values from the TOVA1 and TOVA2 values respectively. Thus a negative change score indicates a decrease in the variable under consideration while a positive change score represents an increase.

Although the use of eleven EEG sites allowed for a more comprehensive examination of the available data, it also created a problem with respect to the large number of statistical comparisons that were completed, resulting in a high probability of Type I Error. Due to the small number of subjects, the exploratory nature of the study, and the importance of detecting potential differences that may exist between the groups, a decision was made to accept the risk of committing Type I Error in order to minimize the risk of Type II Error. Consequently a minimal alpha value of .05 was used and both the analysis of covariance and the analysis of variance results were interpreted without any correction for the number of comparisons that were made. As Duffy (1989) has suggested, chance results occur randomly while true results have the characteristic of being reproducible. Accordingly, one of the goals of the present study was to identify suspected differences or trends between the groups to provide direction for future investigations.

Hypotheses

Given that ADD/H and ADD/WO groups of children have never been directly compared on the basis of their EEG characteristics, the present study was considered to be primarily exploratory in nature. As such, no specific hypotheses were advanced with respect to the differences in EEG characteristics that these two groups of children will exhibit. However, consistent with previous research it was expected that both the ADD/H and ADD/WO groups would exhibit more slow wave activity (i.e., delta and theta) and less fast wave activity (i.e., beta) relative to the control

group. Based on previous research findings, no differences between the ADD/H and ADD/WO groups on the WISC-III or WIAT were expected. A nonsignificant finding between the clinical groups and the control group was also expected given that the subjects were in part selected on the basis of having average to above average intellectual and academic test scores. However, it was hypothesized that the ADD/H and ADD/WO groups would score significantly higher than the controls on both the Response Time and Response Time Variability scores from the TOVA.

CHAPTER IV

RESULTS

Behavior Rating Scales

Table 1 presents the results of the multivariate analysis of variance for the behavior rating scales. The results of this analysis were clearly significant, and the means and standard deviations for the DSM-IV checklist and on the BASC rating scale are presented in Table 2. Post hoc comparisons using the Bonferroni Procedure to control for the rate of Type I error were used to examine the differences between the three groups. With respect to the DSM-IV checklist, the ADD/H group was rated significantly higher than the ADD/WO group on the nine hyperactivity/impulsivity items ($F = 94.74$, $p = .0000$), but there was no difference between these two groups on the nine inattention items ($F = 0.17$, $p = .6856$). The control group was rated significantly lower on the inattention items than either the ADD/WO ($F = 177.27$, $p = .0000$) or the ADD/H group ($F = 166.53$, $p = .0000$), and lower than the ADD/H group on the hyperactivity/impulsivity items ($F = 114.63$, $p = .0000$). There was no difference between the control subjects and the ADD/WO subjects on the hyperactivity/impulsivity items ($F = 0.95$, $p = .34$).

Table 1. Multivariate Analysis of Variance Summary Table for the Behavior Rating Scales

Test	Value	Approximate F	Hypothesized df	Error df	Significance of F
Pillais	1.85229	12.54042	26	26	.000

Table 2 Behavior Rating Scale Results.

	ADD/WO		ADD/H		Control	
DSM-IV Checklist	Mean	SD	Mean	SD	Mean	SD
Inattention	8.33[a]	(0.71)	8.11[a]	(1.27)	1.11[b]	(1.36)
Hyper/Imp	1.44[a]	(1.59)	8.11[b]	(1.17)	0.78[a]	(1.56)
BASC SCALES						
Hyperactivity	57.56[a]	(11.04)	72.22[b]	(10.58)	43.44[c]	(8.59)
Aggression	54.89[a]	(14.56)	69.22[b]	(15.31)	48.89[a]	(7.03)
Conduct Problems	58.22	(15.31)	68.11[a]	(11.40)	47.67[b]	(6.72)
Anxiety	56.44	(13.31)	58.44[a]	(11.83)	47.89[b]	(4.70)
Depression	66.00[a]	(13.06)	76.00[a]	(20.31)	45.89[b]	(5.28)
Somatization	58.11[a]	(8.72)	54.89[a]	(11.88)	44.56[b]	(9.34)
Atypicality	58.78	(7.17)	69.22[a]	(21.95)	47.44[b]	(7.37)
Withdrawal	62.67[a]	(15.29)	54.67[a]	(9.85)	43.00[b]	(6.27)
Attention Problems	71.89[a]	(9.28)	68.56[a]	(8.16)	46.56[b]	(11.22)
Social Skills	42.33[a]	(8.14)	43.33[a]	(8.94)	54.33[b]	(6.89)
Leadership	40.77[a]	(8.80)	45.44[a]	(5.29)	54.33[b]	(5.96)

Note. DSM-IV Checklist results are reported as raw scores. BASC results are reported as T Scores. Scores for Social Skills and Leadership are reversed. The Adaptability Scale from the 6 to 11 year old form of the BASC was excluded from this analysis because it is not included on the 12 to 18 year old version of the BASC; n = 9 for each group. Means with different superscripts are significantly different at the $p<.05$ level. For each contrast $df = 2, 24$.

Post hoc analyses using the Bonferroni Procedure to compare the three groups on the BASC scores were also completed. The ADD/H group was rated significantly higher than the ADD/WO group on the Hyperactivity Scale ($F = 9.44$, $p = .005$), but not on the Attention Problems Scale ($F = 0.54$, $p = .47$). The only other significant difference between these two groups emerged on the Aggression

Scale, with the ADD/H group scoring significantly higher in this regard ($F = 5.59, p = .03$). Although the ADD/H group received a higher rating than the ADD/WO group on the Conduct Problems Scale, this difference did not quite reach significance. However, as expected there were a number of significant differences between the clinical groups and the control group. In particular, the ADD/H subjects were rated as being significantly more maladaptive than the control group on all of the 11 BASC Scales using a alpha level of .05. Similarly, the ADD/WO group obtained significantly higher ratings than the control group on the Hyperactivity, Depression, Somatization, Withdrawal, and Attention Problems Scales. This group was also rated lower on the Social Skills and Leadership Scales than was the control group (the scoring for these two scales is reversed so that lower scores are indicative of maladaptive characteristics). All of these differences were significant at the .05 level.

Psychometric Test Results

Table 3 presents the results of the multivariate analysis of variance for the psychometric data while the means and standard deviations of the WISC-III, WIAT and TOVA scores for each group are summarized in Table 4. For the purposes of this analysis the WISC-III scores were broken down into the following sections: Full Scale IQ (FSIQ), Verbal Comprehension Index (VCI), Perceptual Organization Index (POI), Freedom from Distractibility Index (FDI), and Processing Speed Index (PSI). Although the omnibus test was not significant, post hoc comparisons using the Bonferroni procedure revealed that the ADD/WO group scored significantly lower

than the control group on the PSI ($F = 6.39$, $p = .018$). No other significant differences were found between the three groups on the WISC-III scores or any of the WIAT scores.

Table 3. Multivariate Analysis of Variance Summary Table for Psychometric Data

Test	Value	Approximate F	Hypothesized df	Error df	Significance of F
Pillais	1.08681	1.38847	24	28	.201

Table 4. Psychometric Test Results

	ADD/WO		ADD/H		Control	
VARIABLE	Mean	SD	Mean	SD	Mean	SD
WISC FSIQ	104.89	(9.10)	108.89	(12.33)	109.89	(10.51)
WISC VCI	104.67	(6.06)	110.44	(15.21)	106.33	(11.74)
WISC POI	106.22	(11.36)	111.56	(13.78)	110.67	(10.79)
WISC FDI	97.33	(7.68)	99.67	(12.45)	102.78	(5.56)
WISC PSI	97.56[a]	(13.8)	103.00	(12.63)	112.56[b]	(11.20)
WIAT Reading	105.78	(11.95)	104.11	(10.45)	104.89	(9.63)
WIAT Spelling	98.11	(8.05)	98.11	(8.92)	101.89	(10.89)
WIAT Math Reason	103.22	(11.67)	101.78	(7.87)	107.89	(7.27)
TOVA Omission	62.22	(17.83)	58.11	(4.59)	52.22	(5.07)
TOVA Commission	57.00	(12.27)	61.89	(13.26)	51.44	(10.46)
TOVA Resp Time	71.89	(16.0)	69.78	(18.16)	58.78	(11.71)
TOVA Variability	76.33	(17.29)	90.44[a]	(27.73)	60.33[b]	(4.58)

Note. WISC and WIAT results are Standard Scores. TOVA results are T Scores (higher scores indicate greater impairment). FSIQ = Full Scale Intelligence Quotient, VCI = Verbal Comprehension Index, POI = Perceptual Organization Index, FDI = Freedom from Distractibility Index, PSI = Processing Speed Index. Means with different superscripts are significantly different at the $p<.05$ level; $n = 9$ for each group. For each contrast $df = 2, 24$.

None of the subjects included in the study had unreliable TOVA results based on the criteria outlined in the TOVA Interpretation Manual (Greenberg, 1991). Post hoc comparisons, once again using the Bonferroni Procedure, revealed that the ADD/H group obtained significantly higher Variability scores than the control group ($F = 11.24, p = .003$). The two clinical groups were comparable on all of the TOVA variables with the only exception being that the ADD/H subjects tended to receive higher Variability scores than did the ADD/WO subjects. Nevertheless, this difference was not significant ($F = 2.47, p = .13$). However, there were a number of other observable trends in the data. In particular, the ADD/WO group tended to achieve higher Response Time ($F = 3.07, p = .093$), Variability ($F = 3.17, p = .088$) and Omission scores ($F = 3.70, p = .066$) than did the control group. In addition, the ADD/H subjects tended to score higher on the Commission score than the control group ($F = 3.38, p = .079$).

EEG Analysis of Covariance

A test for homogeneity of regression was conducted on each of the variables in order to confirm the existence of a common slope between the covariate (eyes open) and dependent variables (TOVA1 and TOVA2). The results of these analyses revealed that the assumption of homogeneity of regression required for the analysis of covariance held true for all but the following six variables that emerged as being significant between two or more of the groups: CZ beta1 for the TOVA1 means comparisons, and F3 SMR, F4 SMR, FZ SMR, P3 SMR, and PZ SMR for the

TOVA2 standard deviation comparisons. Consequently these six variables were excluded from the analysis of covariance results tables. Since both the covariate (eyes open condition) and the dependent variables (TOVA1 and TOVA2 conditions) are measures of EEG magnitude from the same subjects, it is reasonable to assume that there is a linear (rather than a curvilinear) relationship between them, thereby satisfying the second basic assumption required for analysis of covariance. Only significant findings ($p < .05$) are reported for each of the analysis of covariance results tables. Both the obtained means and the adjusted means are provided for comparison purposes.

The results of the analysis of covariance for the TOVA1 means are presented in Table 5. The two clinical groups differed significantly on only one variable, that being O2 SMR, with the ADD/WO subjects obtaining a significantly higher adjusted mean than their hyperactive counterparts. The ADD/WO group had a significantly higher adjusted mean magnitude than the control group on all of the 21 variables listed in Table 5. In comparison, the ADD/H subjects had higher means than the control group on only two of the variables: O1 theta and O2 delta.

There are also a number of consistent trends in the TOVA1 means results. With the sole exception of O2 delta, the ADD/WO group have the highest adjusted means on all of the variables, followed by the ADD/H and then the control group. The adjusted means for the control group were the lowest across all 21 of the variables reported in Table 5. Looking at the obtained means, the ADD/WO group

Table 5. Analysis of Covariance TOVA1 Means

Variable	ADD/WO		ADD/H		Control	
	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean
C4 theta	23.5	23.21[a]	20.64	22.37	23.12	21.69[b]
CZ alpha	19.31	18.43[a]	15.66	17.70	17.53	16.37[b]
CZ delta	28.51	29.51[a]	29.26	29.21	28.07	27.12[b]
CZ theta	26.17	26.32[a]	23.60	25.57	26.49	24.37[b]
F3 alpha	15.96	15.47[a]	13.63	14.57	14.49	14.04[b]
F4 alpha	16.19	15.78[a]	14.06	14.96	14.74	14.25[b]
FZ alpha	16.49	15.98[a]	14.21	15.19	14.83	14.35[b]
O1 SMR	11.33	11.51[a]	9.82	10.61	11.16	10.19[b]
O1 theta	20.93	20.59[a]	18.53	20.48[a]	20.10	18.49[b]
O2 beta1	8.44	8.51[a]	7.76	7.84	7.56	7.41[b]
O2 delta	27.09	28.27[a]	28.05	28.33[a]	27.00	25.54[b]
O2 SMR	11.92	12.15[a]	10.12	10.73[b]	11.17	10.34[b]
P3 alpha	20.90	20.66[a]	17.14	19.49	19.34	17.23[b]
P3 beta1	8.12	7.62[a]	6.68	7.23	7.07	7.00[b]
P3 SMR	10.80	10.28[a]	8.87	9.98	10.13	9.54[b]
P4 beta1	8.26	7.73[a]	6.60	7.12	6.98	6.98[b]
P4 delta	28.39	29.14[a]	27.61	27.83	27.37	26.40[b]
PZ alpha	21.99	21.81[a]	18.51	20.78	20.71	18.62[b]
PZ beta1	7.96	7.59[a]	6.51	7.00	6.94	6.82[b]
PZ delta	28.37	29.65[a]	28.73	28.92	28.28	26.81[b]
PZ SMR	10.54	10.10[a]	8.91	9.89	10.02	9.47[b]

Note. Means with different superscripts are significantly different at the $p<.05$ level. $df = 2, 23$.

once again tended to have the highest values (16 out of 21 variables), but the ADD/H group tended to achieve the lowest values (14 out of 21 variables) with the control group typically falling somewhere in between. The only notable exceptions occurred for the following five variables where the ADD/H subjects actually achieved the highest obtained means: CZ delta, CZ theta, F3 alpha, O2 delta, and PZ SMR.

Table 6 summarizes the results of the analysis of covariance for the TOVA2 means. The two clinical groups differed significantly on only two of the variables (O2 SMR and P4 SMR), and in both instances the ADD/WO subjects had higher

Table 6. Analysis of Covariance TOVA2 Means

Variable	ADD/WO		ADD/H		Control	
	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean
C3 theta	23.39	23.05[a]	20.99	22.77	22.76	21.31[b]
CZ theta	26.20	26.35[a]	23.98	25.93	25.83	23.73[b]
F4 delta	27.08	27.20	28.44	27.92[a]	25.87	26.26[b]
O1 delta	24.86	26.41	27.88	28.32[a]	26.64	24.65[b]
O1 theta	21.31	20.95	19.46	21.55[a]	20.77	19.04[b]
O2 beta2	6.44	6.35	6.52	6.54[a]	5.46	5.53[b]
O2 SMR	12.00	12.19[a]	10.30	10.80[b]	11.48	10.78[b]
P3 beta2	5.56	5.14	5.08	5.45[a]	4.98	5.02[b]
P3 delta	26.62	27.50	28.47	28.75[a]	26.62	25.47[b]
P4 SMR	11.24	10.85[a]	9.06	9.93[b]	10.54	10.06
PZ delta	29.99	29.72[a]	29.68	29.93[a]	28.48	26.49[b]

Note. Means with different superscripts are significantly different at the $p<.05$ level. $df = 2, 23$.

adjusted mean magnitudes than the ADD/H subjects. In contrast to the findings associated with the TOVA1 condition, over half of the significant differences that emerged were between the ADD/H subjects and the control subjects, and in each case the ADD/H group obtained a higher adjusted mean magnitude. The adjusted mean magnitude for the ADD/WO group was significantly higher than that of the control group on four variables.

One of the two clinical groups emerged with the highest adjusted mean on each of the 11 variables listed in Table 6. In all but one instance (P4 SMR) the control group had the lowest adjusted TOVA2 mean. The pattern of values for the obtained means is less consistent, with the only observable trend being that either the ADD/WO or the ADD/H group achieved the highest obtained mean on each of the 11 variables.

The results from the analysis of covariance for the TOVA1 standard deviations are presented in Table 7. The majority of the significant differences occurred between the ADD/WO and ADD/H groups, with the former having significantly larger adjusted mean standard deviations. There are also a number of significant differences between the ADD/WO group and the control group, once again with the former having larger adjusted standard deviations. The ADD/H group and the control group were not significantly different on any of the TOVA1 standard deviation variables. An examination of the adjusted means in Table 7 reveals that the value for the ADD/WO group was consistently the highest with either the ADD/H group or the control group being the lowest. A similar pattern emerged for the

Table 7. Analysis of Covariance TOVA1 Standard Deviations

Variable	ADD/WO		ADD/H		Control	
	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean
C3 SMR	3.56	3.33[a]	2.60	2.71[b]	2.89	3.00
C3 theta	7.59	7.76[a]	6.33	6.77[b]	7.52	6.91
CZ theta	8.68	8.84[a]	7.78	8.35	8.56	7.82[b]
F3 theta	8.14	8.26[a]	6.71	6.86[b]	7.62	7.35
F4 alpha	5.43	5.33[a]	4.62	4.59[b]	4.86	4.98
F4 theta	8.17	8.35[a]	7.11	7.08[b]	7.68	7.53
O1 SMR	3.96	4.16[a]	3.29	3.81	3.84	3.12[b]
O1 theta	7.18	7.38[a]	6.21	6.84	6.82	5.99[b]
P3 theta	8.04	8.26[a]	6.37	7.08[b]	7.80	6.87[b]

Note. Means with different superscripts are significantly different at the $p<.05$ level. $df = 2, 23$.

obtained means. Once again the ADD/WO subjects had the highest means across all nine variables, but in this case the ADD/H subjects consistently achieved the lowest mean scores.

Table 8 summarizes the analysis of covariance results for the TOVA2 standard deviations. Three of the five significant differences occurred between the ADD/WO group and the control group, and in each case the ADD/WO subjects had larger adjusted mean standard deviations. The ADD/WO group exceeded the ADD/H group on one variable (P4 SMR) as did the control group (C3 SMR). Although the ADD/WO subjects tended to achieve the highest adjusted means and the highest

Table 8. Analysis of Covariance TOVA2 Standard Deviations

Variable	ADD/WO		ADD/H		Control	
	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean	Obtained Mean	Adjusted Mean
C3 SMR	3.46	3.22	2.43	2.54[a]	3.32	3.44[b]
C3 theta	7.71	7.86[a]	6.53	6.90	7.14	6.63[b]
C4 theta	7.72	7.87[a]	6.64	7.16	7.11	6.43[b]
O1 SMR	3.79	3.93[a]	3.24	3.60	3.66	3.16[b]
P4 SMR	4.09	3.80[a]	2.80	3.12[b]	3.73	3.70

Note. Means with different superscripts are significantly different at the $p<.05$ level. $df = 2, 23$.

obtained means. The lowest adjusted means where split between the ADD/H and control groups, while the ADD/H group achieved the lowest obtained means on all five of the variables listed in Table 8.

EEG Change Scores

The results of the analysis of variance on the change scores for the TOVA1 means are summarized in Figures 1 to 11. All of the variables are presented so as to facilitate a more thorough examination of the trends in the data, and standard deviations are depicted using error bars. The two clinical groups did not differ significantly on any of the TOVA1 means change scores. The vast majority of the significant differences that did emerge (20 out of 23) were between the ADD/WO group and the control group, and most of these occurred at the occipital or parietal

Figure 1. Change in mean magnitude from eyes open to TOVA1 at C3.

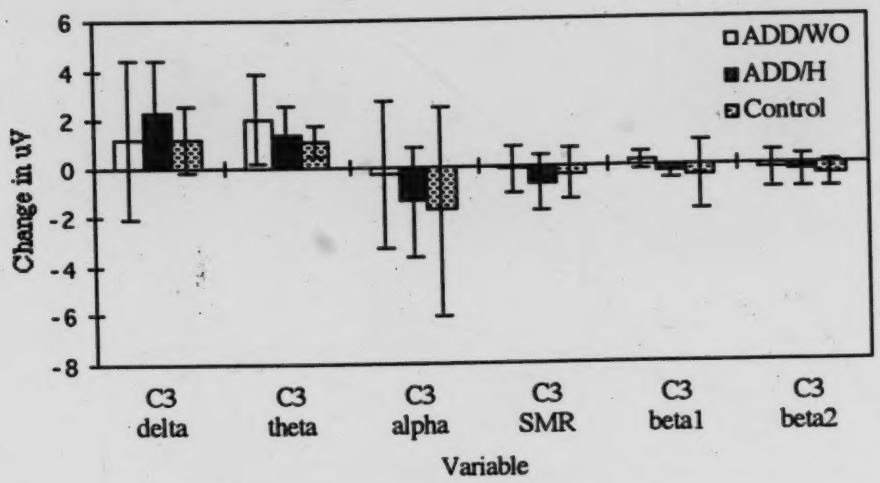
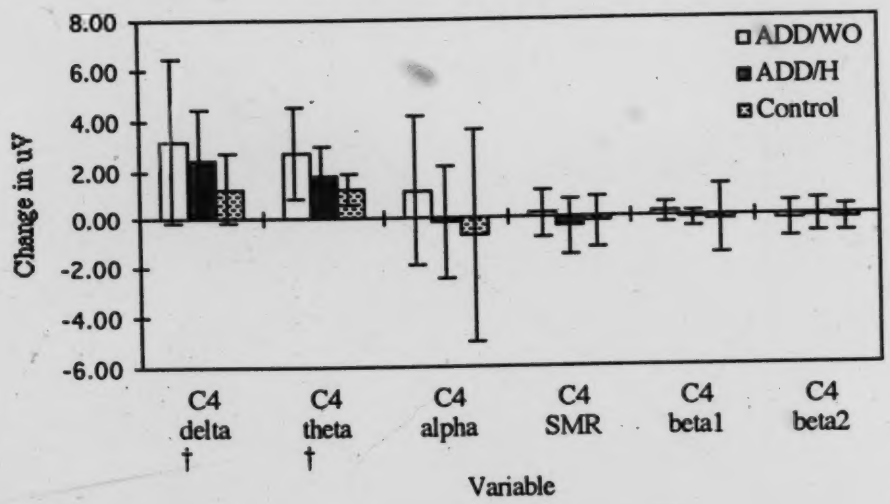


Figure 2. Change in mean magnitude from eyes open to TOVA1 at C4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 3. Change in mean magnitude from eyes open to TOVA1 at CZ.

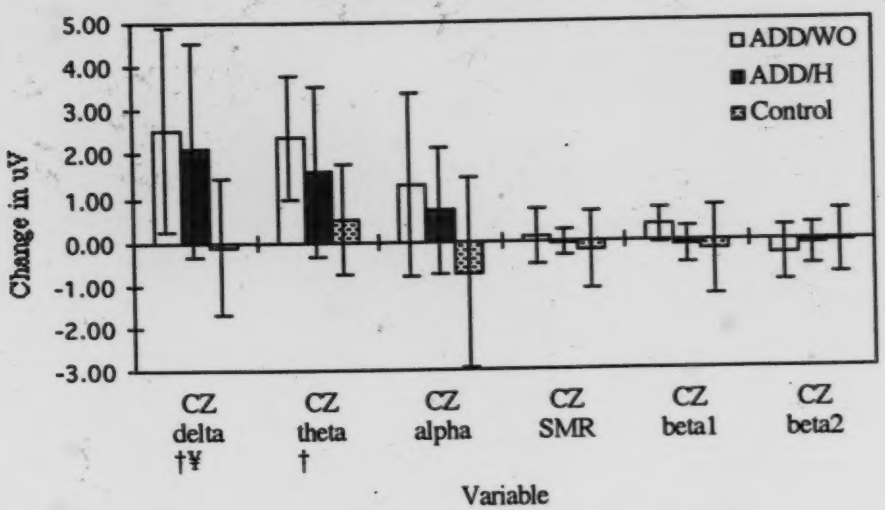
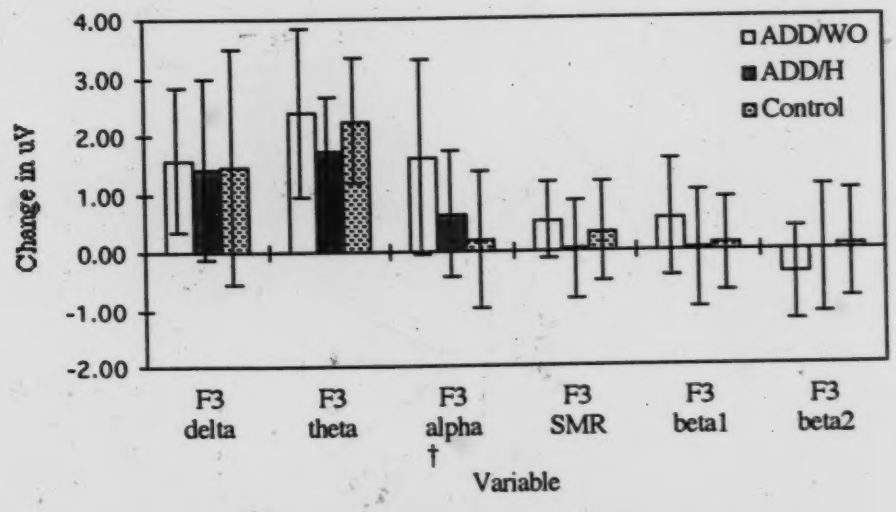


Figure 4. Change in mean magnitude from eyes open to TOVA1 at F3.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 5. Change in mean magnitude from eyes open to TOVA1 at F4.

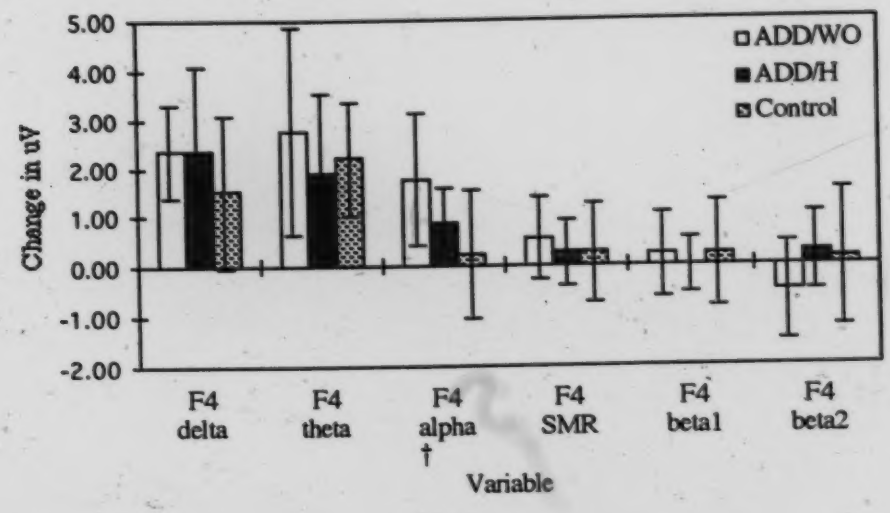
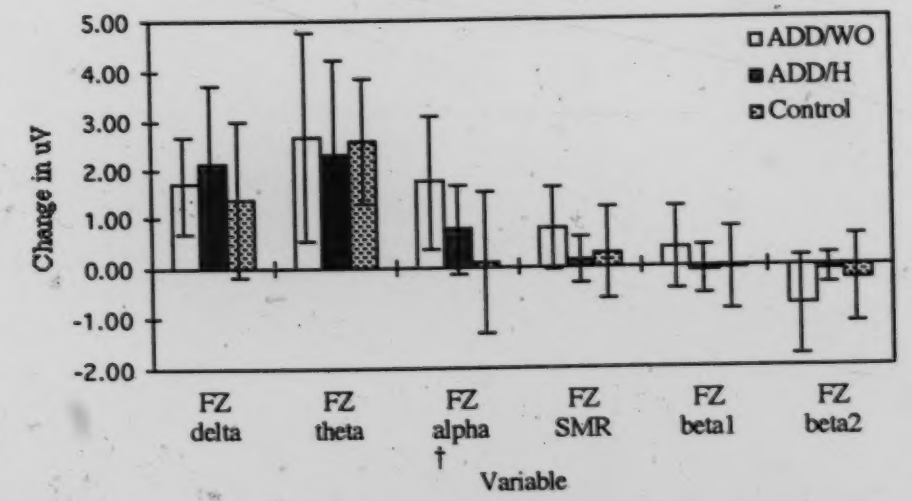


Figure 6. Change in mean magnitude from eyes open to TOVA1 at FZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 7. Change in mean magnitude from eyes open to TOVA1 at O1.

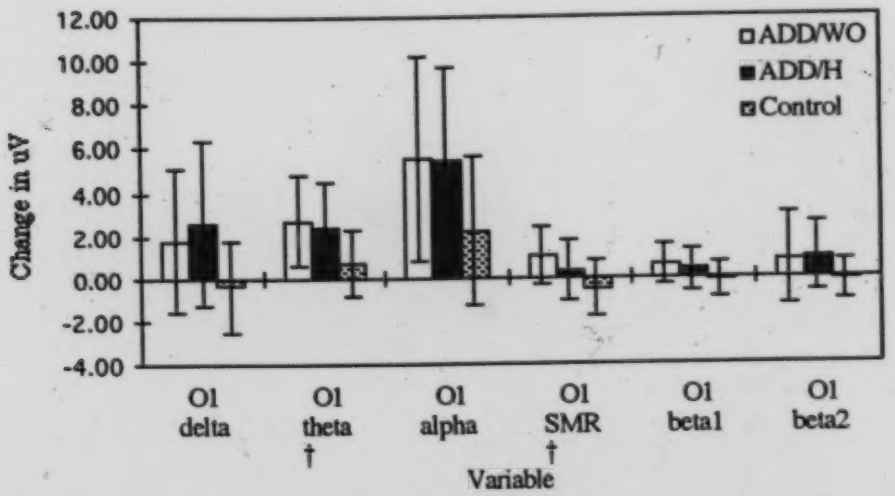
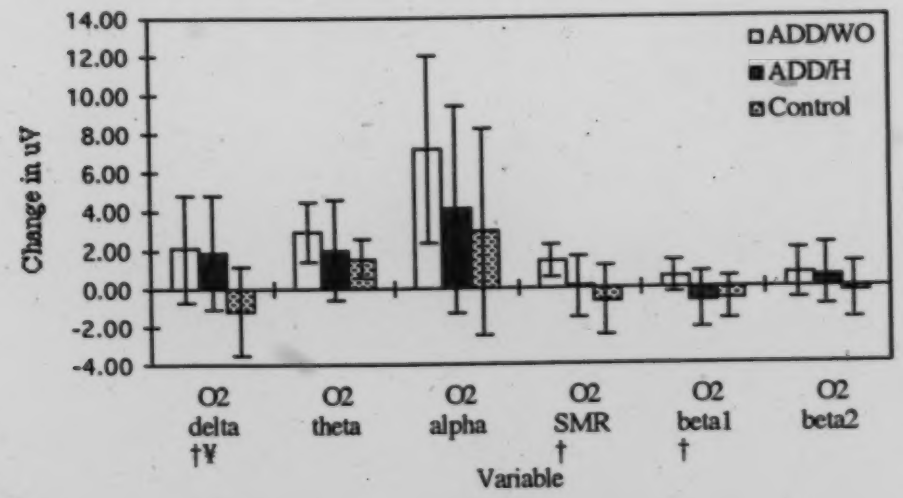


Figure 8. Change in mean magnitude from eyes open to TOVA1 at O2.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 9. Change in mean magnitude from eyes open to TOVA1 at P3.

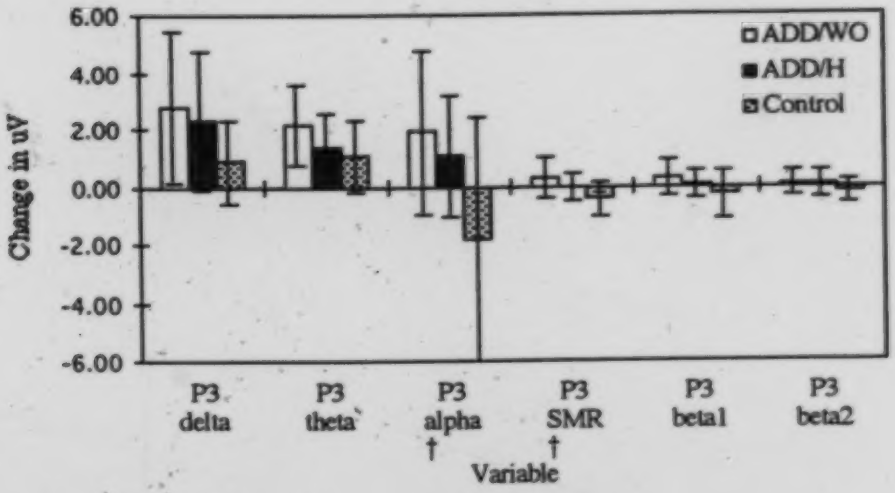
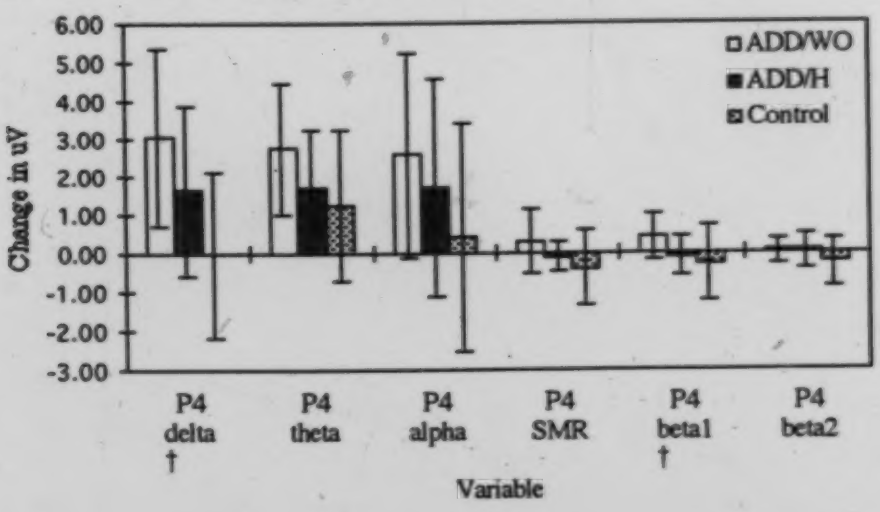
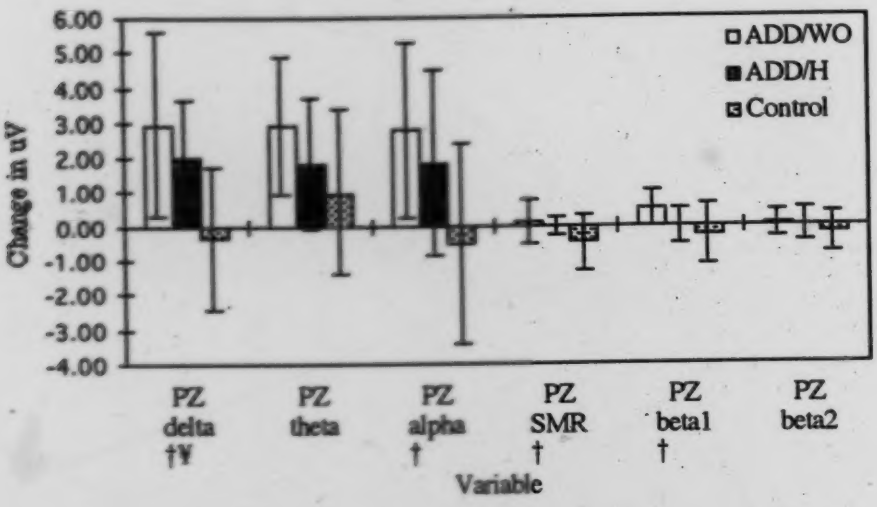


Figure 10. Change in mean magnitude from eyes open to TOVA1 at P4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 11. Change in mean magnitude from eyes open to TOVA1 at PZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

sites. In each of these instances the mean change score for the ADD/WO subjects was significantly higher than what the control subjects demonstrated. Recalling that a positive change score indicates an increase (from the eyes open condition to the TOVA1 condition) in the variable under consideration, this result suggests that as a group the ADD/WO subjects exhibited a significantly greater increase on each of these variables than did the control subjects. In fact, on 12 of the variables where a significant difference emerged, the ADD/H group displayed a mean increase while the control group displayed a mean decrease. Once again, the majority of these cases where clustered in the occipital and parietal sites. The ADD/H group differed from

the control group on three of the variables: CZ delta, O2 delta, and PZ delta. In each case the ADD/H group increased their production of delta while the control group evidenced a decrease in their delta production.

The largest changes in mean magnitude from eyes open to TOVA1 for all three groups occurred in the delta, theta and alpha bandwidths. With exception of C3 and C4 alpha, the two clinical groups increased their production in these slower bandwidths across all sites. While the control group also displayed an increase in these bandwidths at the frontal sites, it was generally less pronounced than what was observed for the clinical groups. This trend became even more apparent at the parietal and occipital sites where the ADD/WO and ADD/H groups consistently increased their production of delta, theta and alpha, while the control group sometimes evidenced a decrease in these bandwidths (particularly delta). Both the ADD/WO and the ADD/H group typically increased the amount of alpha they produced, while the control group exhibited either a more moderate increase or actually decreased their alpha production. Five of the differences in alpha change scores between the ADD/WO group and the control group were statistically significant.

Relatively speaking, all three groups exhibited little change in the mean magnitude of SMR, beta1 and beta2 from the eyes open to the TOVA1 condition. However, there were some notable differences between the ADD/WO and the control group at the occipital and parietal sites. In each case the ADD/WO subjects produced

higher SMR, beta1 and beta2 mean magnitudes while the control subjects displayed a decrease in these values. Seven of these variables emerged as significantly different.

The results of the analysis of variance on the change scores for the TOVA2 means are presented in Figures 12 to 22. Overall there were less than half the number of significant findings compared to what emerged from the TOVA1 mean change scores. Only one variable, P3 beta2, reached statistical significance between the two clinical groups. The ADD/H group achieved a small positive change score on this variable while the ADD/WO group demonstrated a very small change in the negative direction. The ADD/WO group differed significantly from the control group on four variables (C3 theta, CZ theta, O1 SMR, and O2 SMR). In each case the ADD/WO subjects obtained a higher mean change score, indicating that as a group they displayed a significantly greater positive increase in mean magnitude than did the control subjects. There were also a number of significant differences between the ADD/H group and the control group. Specifically, the ADD/H group exhibited higher mean change scores than did the control group for the following variables: F4 delta, O1 delta, P3 delta, P3 beta2, and PZ delta.

Similar to what was observed in the TOVA1 mean magnitude change scores, the largest TOVA2 change scores occurred in the delta, theta, and alpha bandwidths. For the most part, the two clinical groups tended to increase their production of slow wave activity to a greater extent than did the control group, but there were a number of instances where the control group eclipsed one or both of the clinical groups in this regard.

Figure 12. Change in mean magnitude from eyes open to TOVÁ2 at C3.

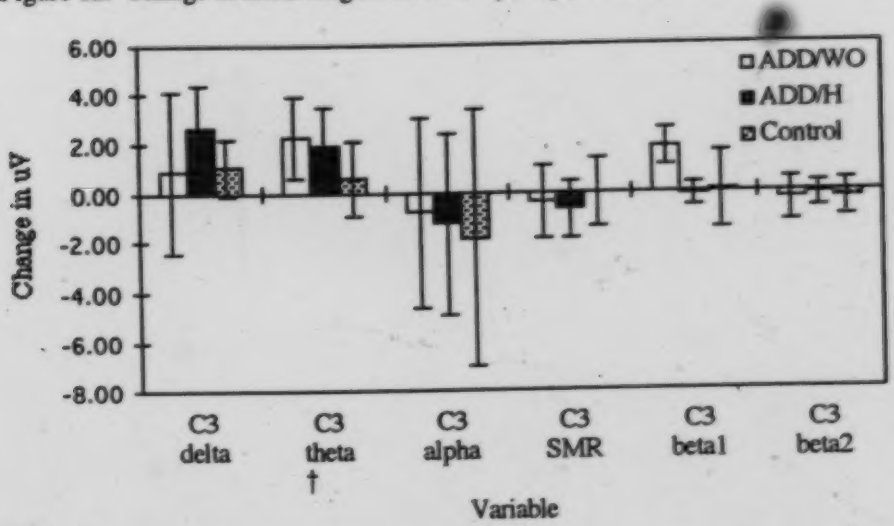
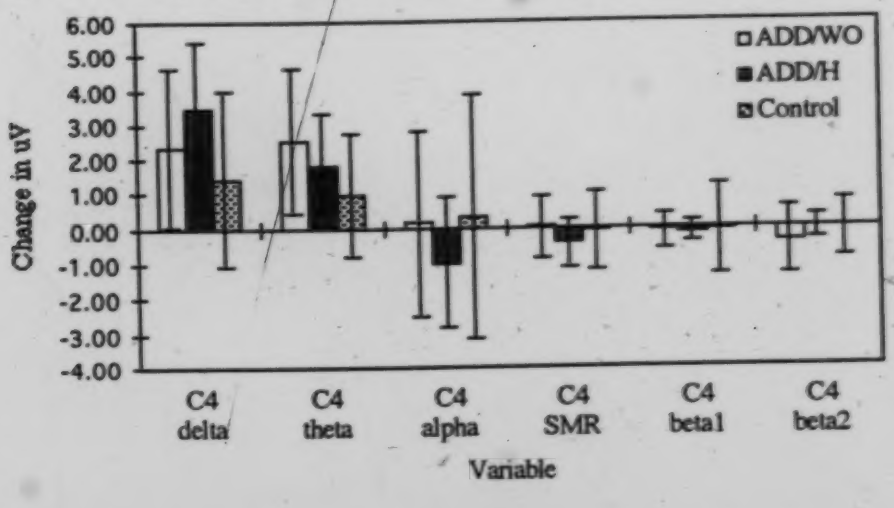


Figure 13. Change in mean magnitude from eyes open to TOVA2 at C4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 14. Change in mean magnitude from eyes open to TOVA2 at CZ.

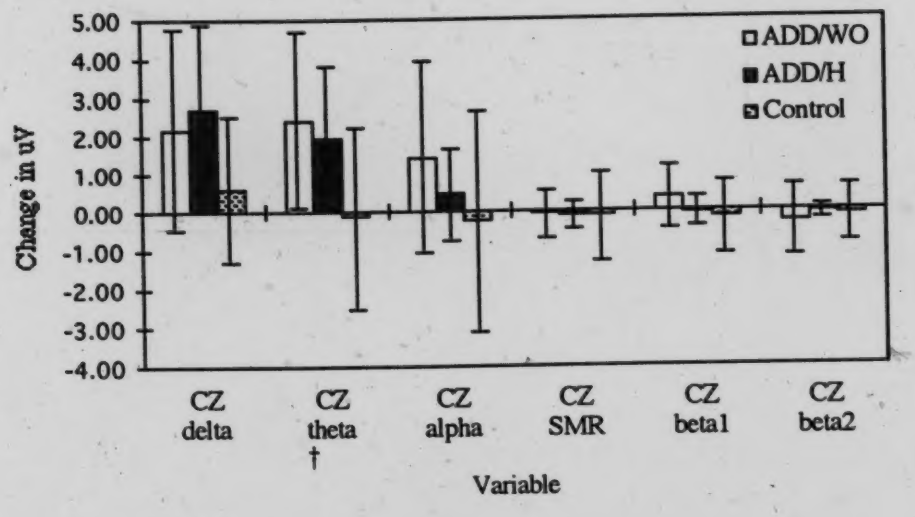
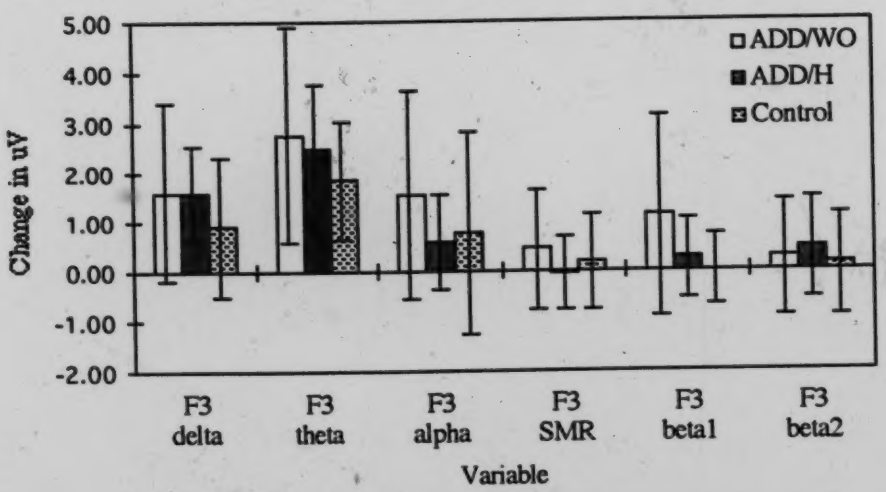


Figure 15. Change in mean magnitude from eyes open to TOVA2 at F3.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 16. Change in mean magnitude from eyes open to TOVA2 at F4.

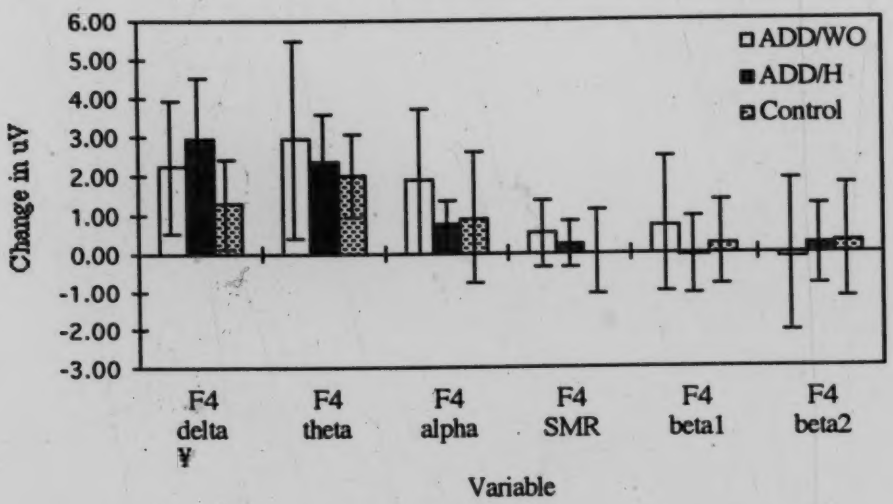
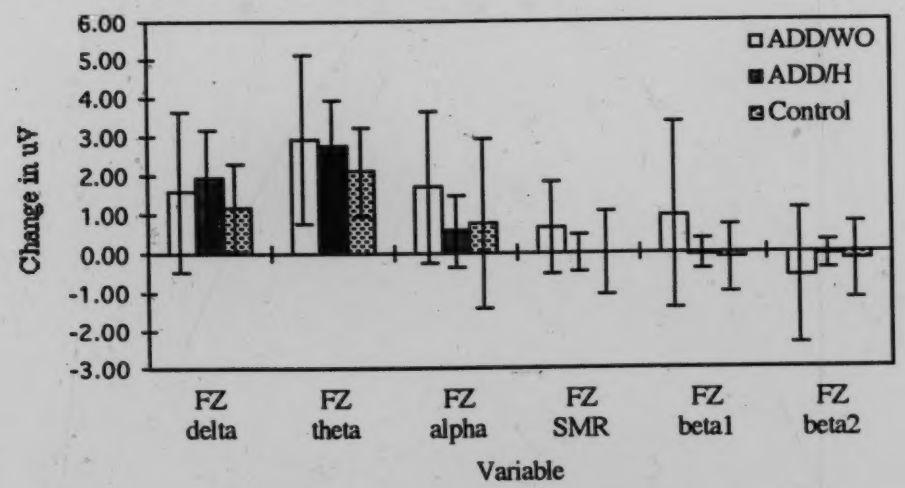


Figure 17. Change in mean magnitude from eyes open to TOVA2 at FZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 18. Change in mean magnitude from eyes open to TOVA2 at O1.

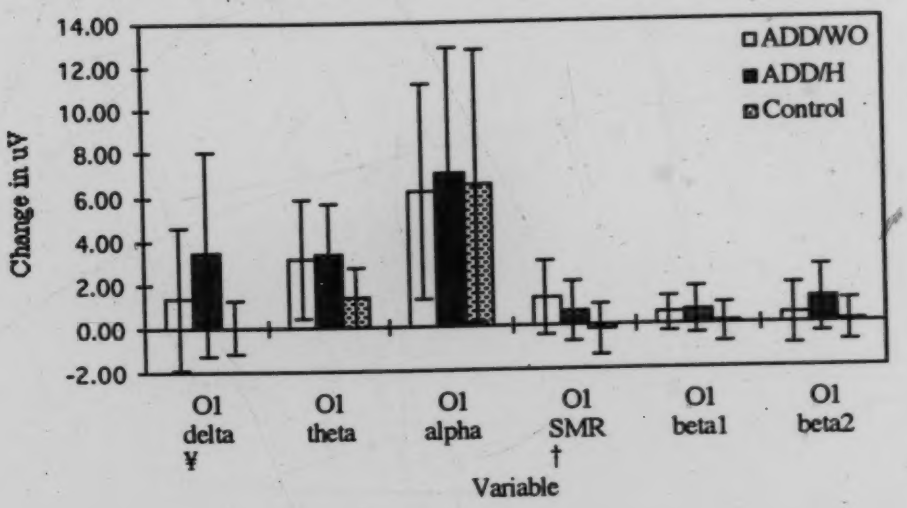
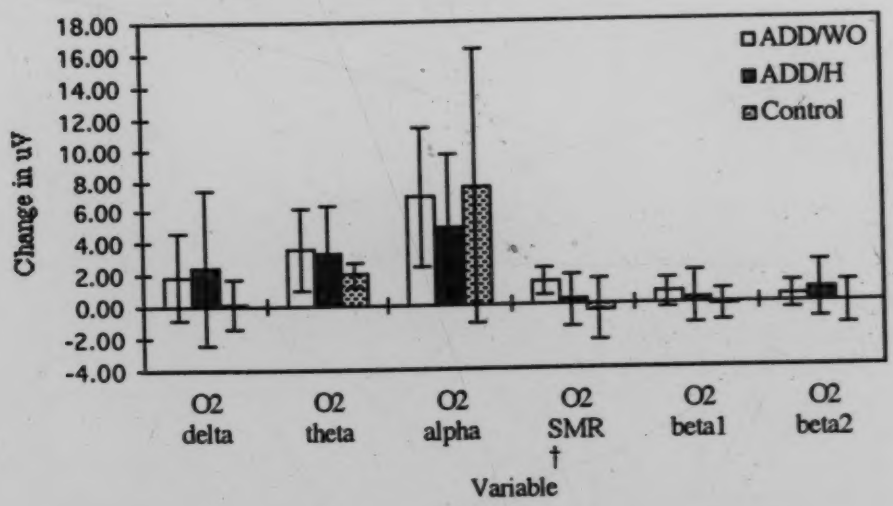


Figure 19. Change in mean magnitude from eyes open to TOVA2 at O2.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 20. Change in mean magnitude from eyes open to TOVA2 at P3.

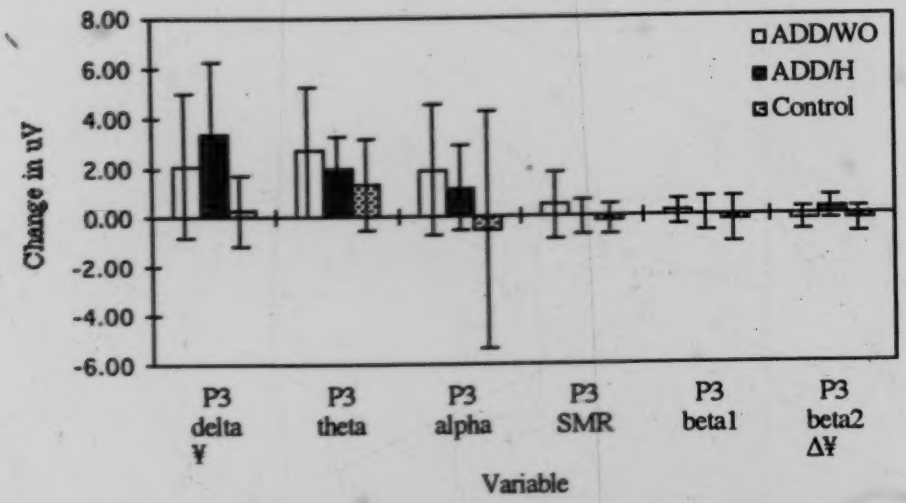
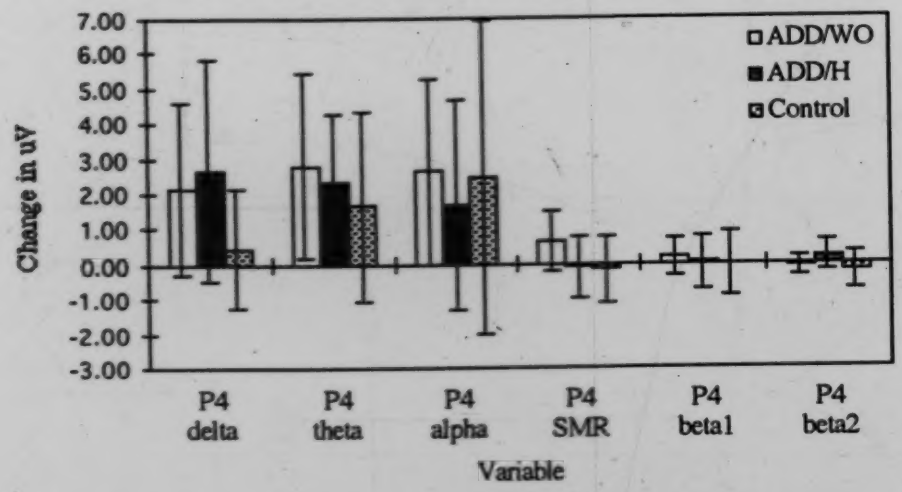
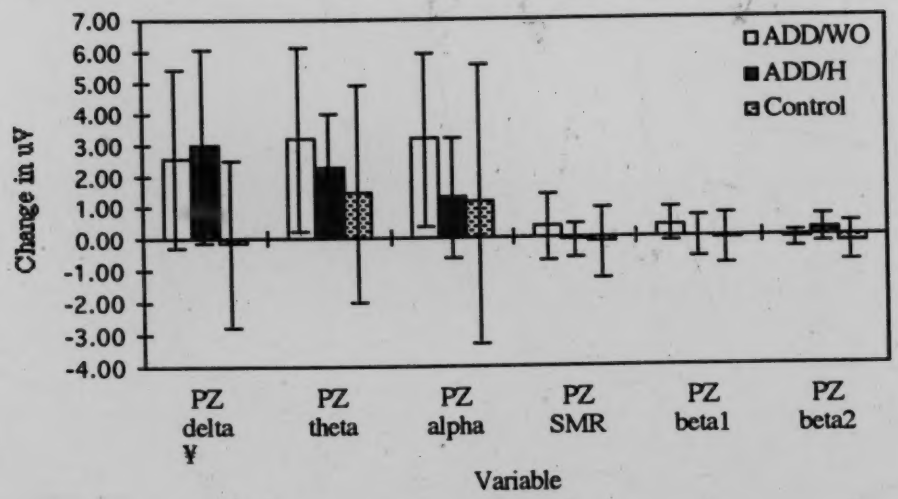


Figure 21. Change in mean magnitude from eyes open to TOVA2 at P4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 22. Change in mean magnitude from eyes open to TOVA2 at PZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

The change in magnitude standard deviation from the eyes open condition to the TOVA1 condition are presented in Figures 23 to 33. F3 theta and F4 theta were the only variables that differentiated between the two clinical groups. In both cases the ADD/WO group achieved significantly higher change scores, indicating that the amount of within-subject variability in alpha exhibited by the ADD/WO subjects at these sites increased significantly more than it did for the subjects in the ADD/H group. The ADD/WO and control groups were significantly different on eight of the variables, most of these occurring in the theta bandwidth at the central, parietal and occipital sites. For all of these variables, the ADD/WO subjects exhibited

Figure 23. Change in magnitude standard deviation from eyes open to TOVA1 at C3.

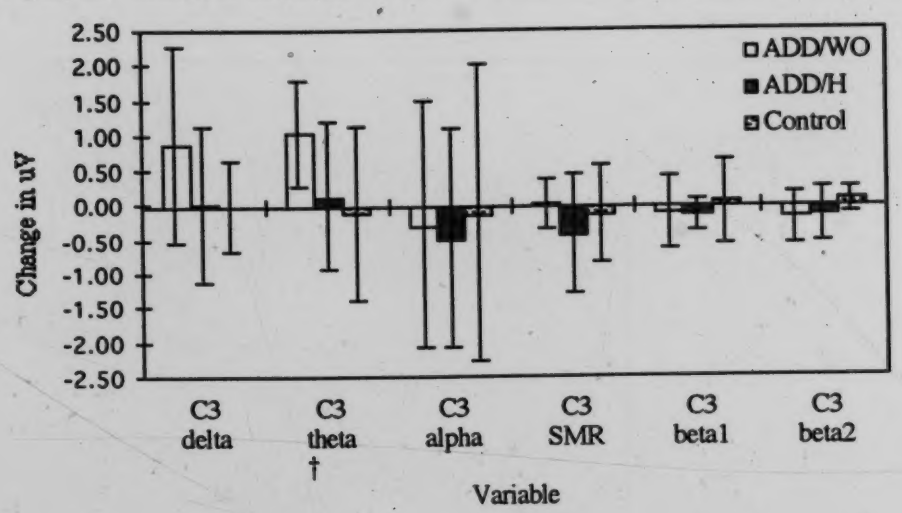
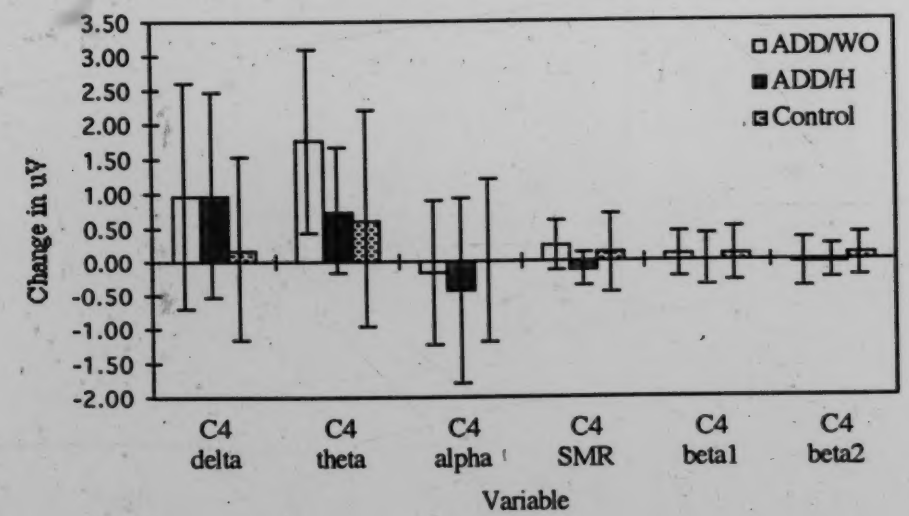


Figure 24. Change in magnitude standard deviation from eyes open to TOVA1 at C4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 25. Change in magnitude standard deviation from eyes open to TOVA1 at CZ.

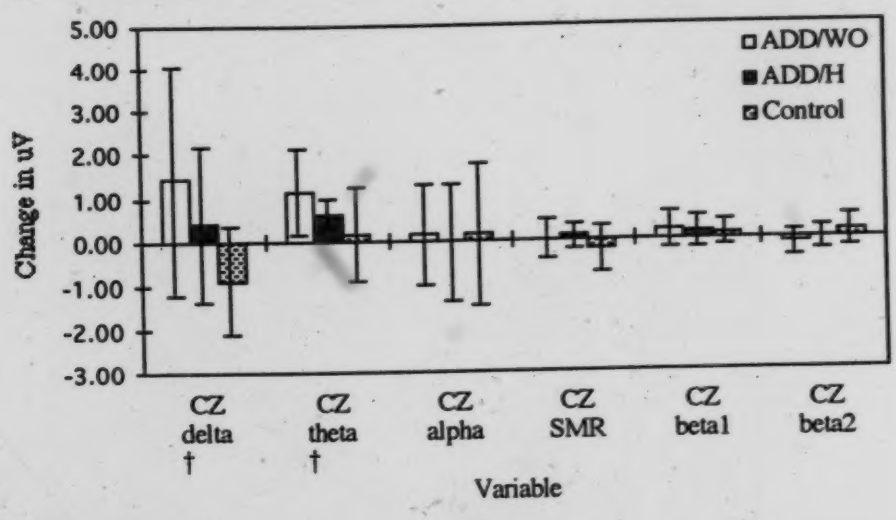
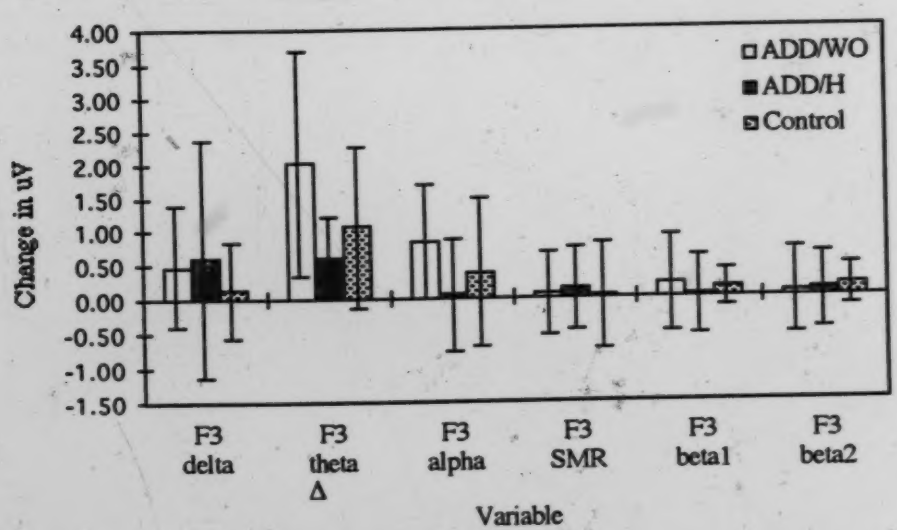


Figure 26. Change in magnitude standard deviation from eyes open to TOVA1 at F3.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 27. Change in magnitude standard deviation from eyes open to TOVA1 at F4.

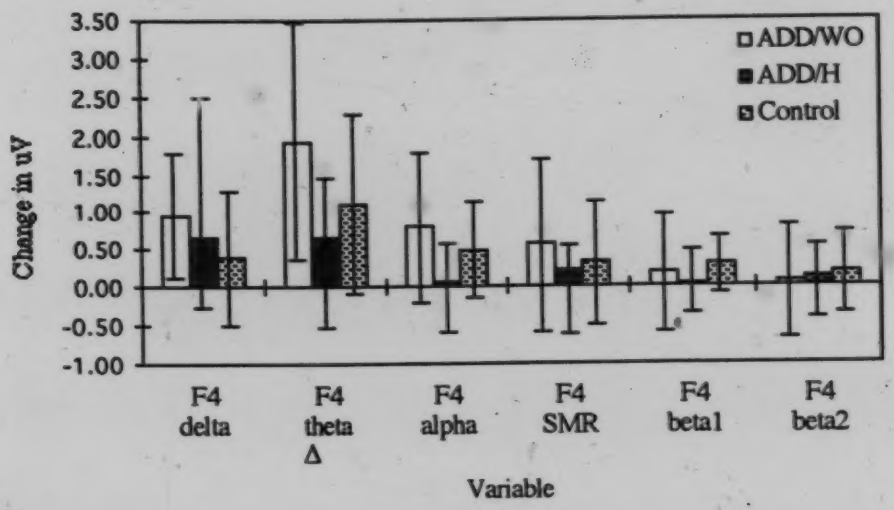
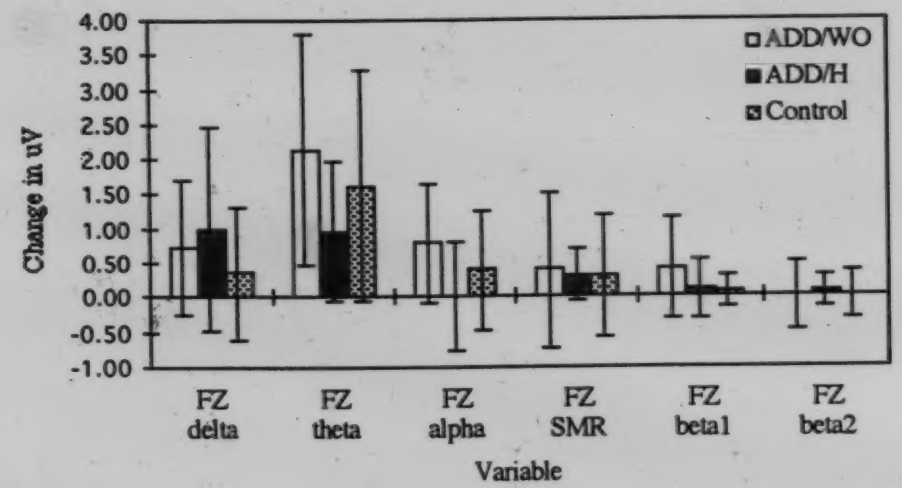


Figure 28. Change in magnitude standard deviation from eyes open to TOVA1 at FZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 29. Change in magnitude standard deviation from eyes open to TOVA1 at O1

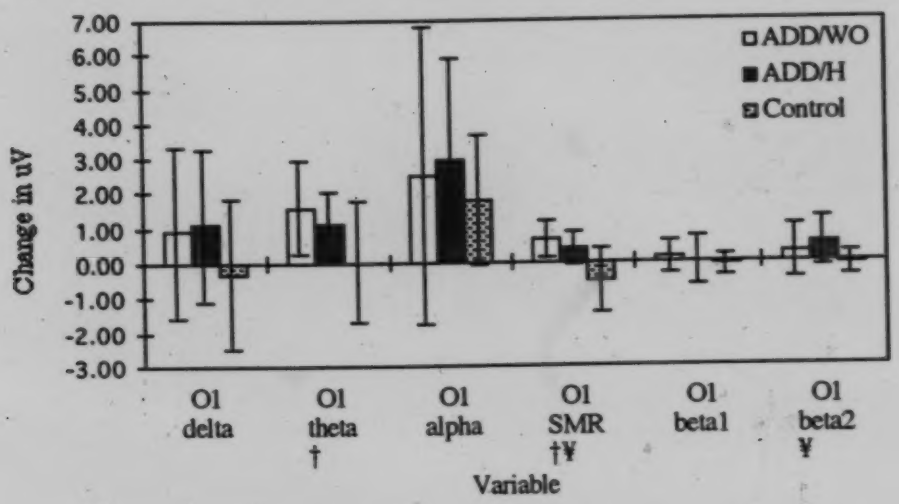
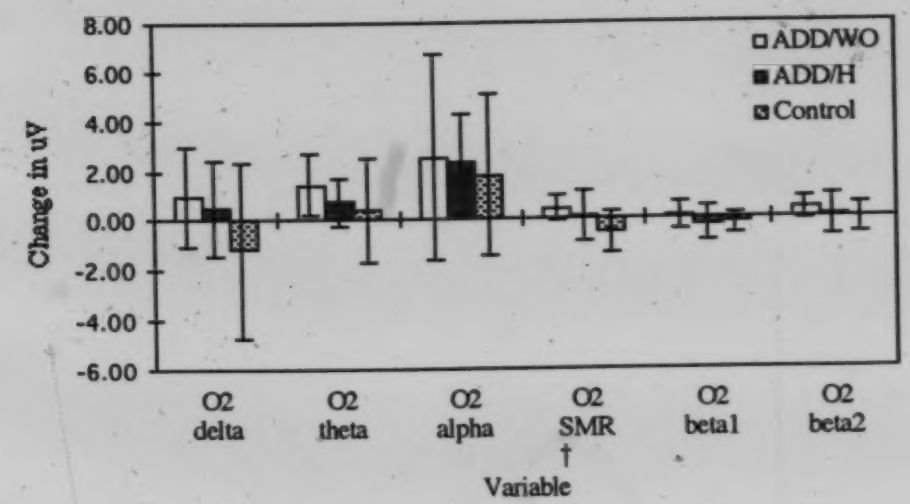


Figure 30. Change in magnitude standard deviation from eyes open to TOVA1 at O2.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 31. Change in magnitude standard deviation from eyes open to TOVA1 at P3.

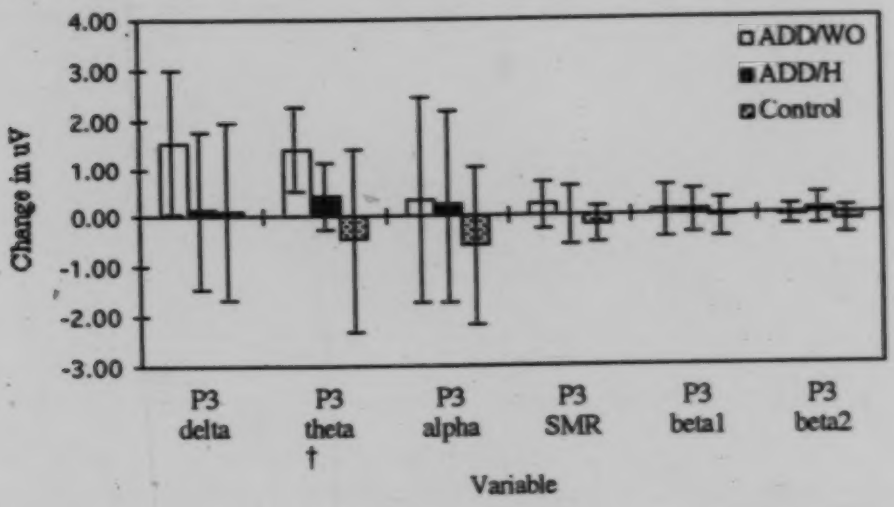
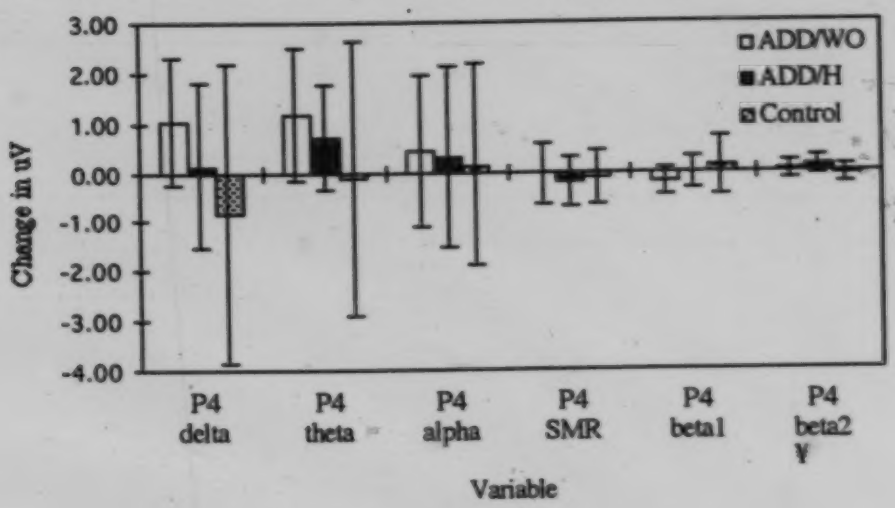
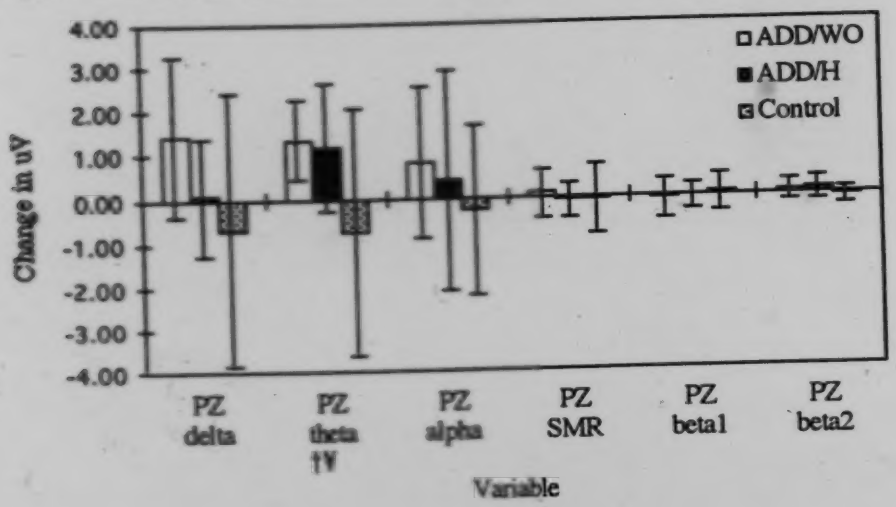


Figure 32. Change in magnitude standard deviation from eyes open to TOVA1 at P4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 33. Change in magnitude standard deviation from eyes open to TOVA1 at PZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

significantly higher change scores than the control subjects. The ADD/H and the control groups were significantly different on four of the TOVA1 standard deviation change scores, all of these occurring in occipital and parietal sites. Again, in each case the ADD/H group achieved higher change scores than the control group.

A visual examination of Figures 23 to 33 reveals some consistent trends in the data. As with the mean magnitude change scores presented earlier, the largest change scores in the TOVA1 standard deviation results occurred in the lower bandwidths, primarily delta and theta. The ADD/WO subjects generally exhibited the greatest increase in standard deviation at these bandwidths, followed by the ADD/H

and control subjects respectively. The only exceptions were at the frontal sites where the ADD/H group achieved lower change scores than both the ADD/WO group and the control group. Change scores in the SMR, beta1 and beta2 bandwidths were quite small with the possible exception of the F4 and FZ sites where all three groups exhibited an increase in standard deviation in the higher frequencies.

The results of the TOVA2 standard deviation change scores are summarized in Figures 34 to 44. The ADD/H group displayed a significantly higher change score than the ADD/WO group at C4 beta2, while the opposite was true for the P3 SMR variable where the ADD/WO group obtained a significantly higher change score. No other significant differences emerged between the two clinical groups. Eight of the variables differentiated between the ADD/WO subjects and the control subjects. The former group obtained significantly higher change scores in the theta band at C3, C4, O1 and P3, and in the SMR band at O1 and O2. The opposite was true for variables C3 beta2 and C4 beta2 where the control group exhibited significantly higher change scores than the ADD/WO group. The ADD/H group evidenced significantly higher standard deviation change scores than the control group on three of the variables (O1 SMR, O1 beta2, and P3 beta2), and a lower change score on C3 SMR. In keeping with what was reported previously, the largest change scores were once again found in the delta, theta and alpha bandwidths, with the two clinical groups typically exhibiting the greatest change.

Figure 34. Change in magnitude standard deviation from eyes open to TOVA2 at C3.

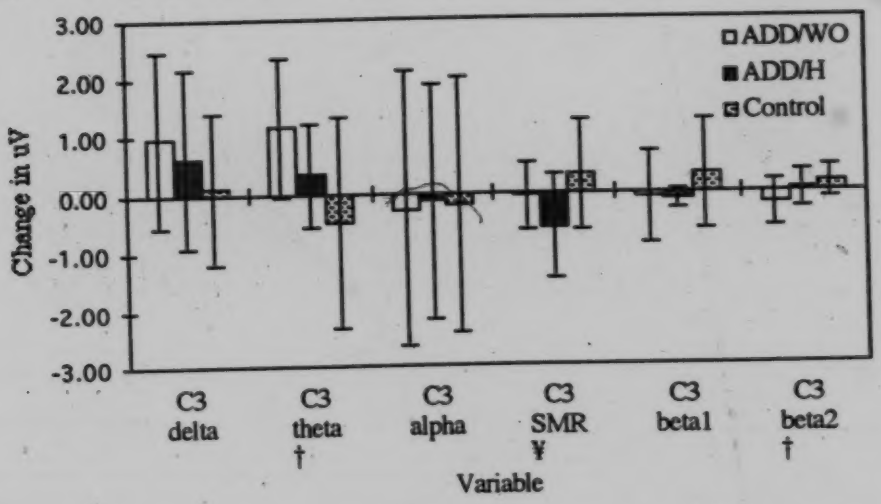
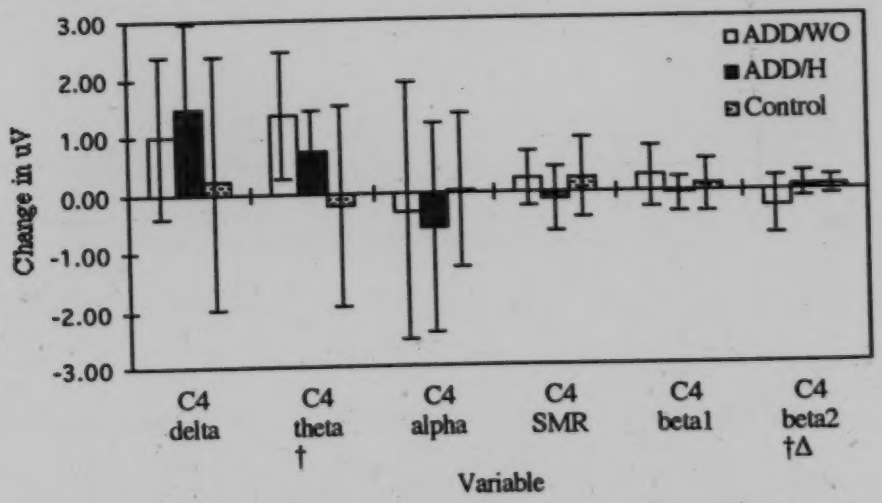


Figure 35. Change in magnitude standard deviation from eyes open to TOVA2 at C4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 36. Change in magnitude standard deviation from eyes open to TOVA2 at CZ.

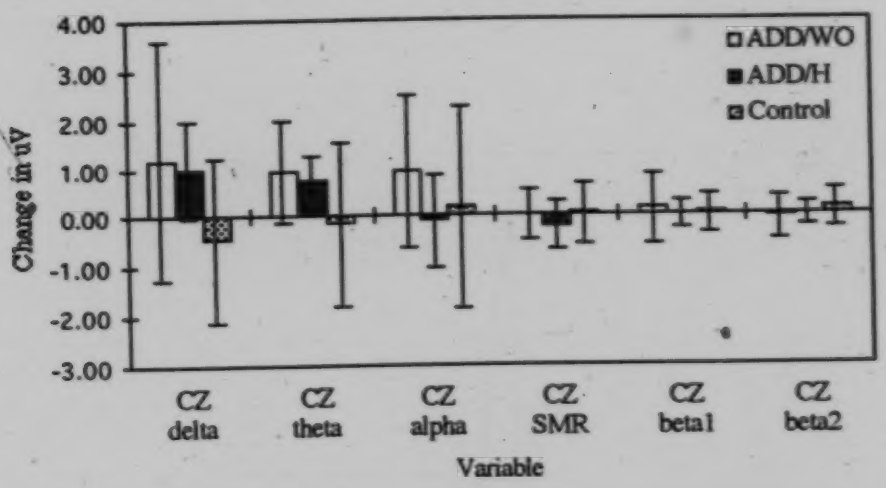
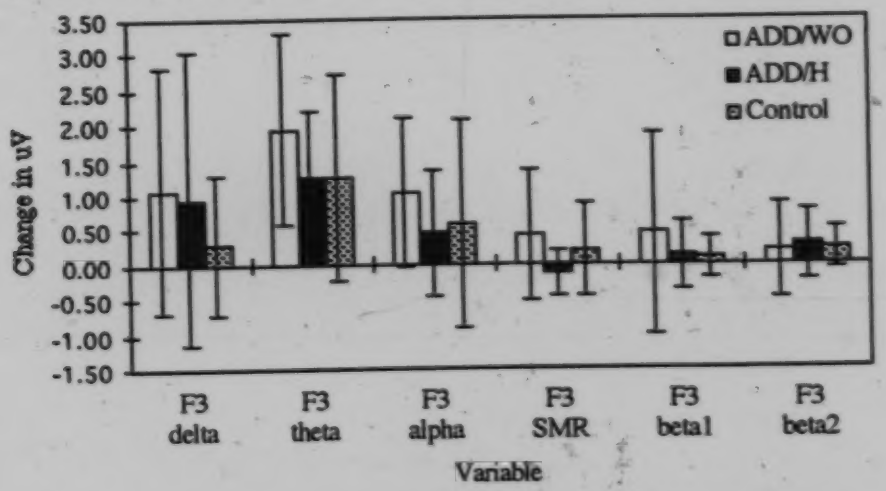


Figure 37. Change in magnitude standard deviation from eyes open to TOVA2 at F3.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 38. Change in magnitude standard deviation from eyes open to TOVA2 at F4.

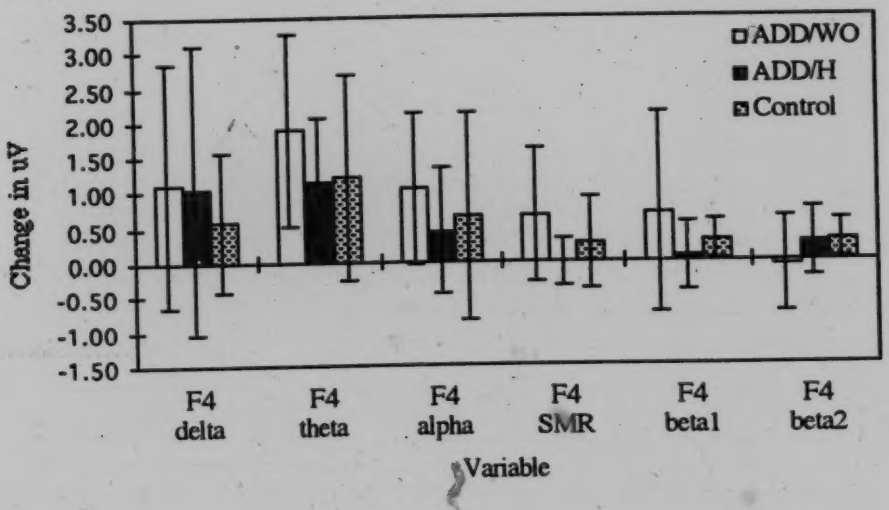
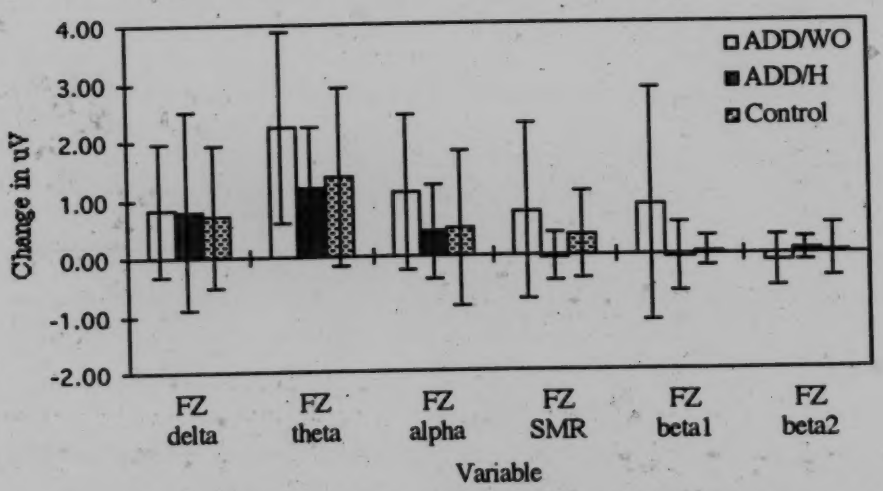


Figure 39. Change in magnitude standard deviation from eyes open to TOVA2 at FZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 40. Change in magnitude standard deviation from eyes open to TOVA2 at O1.

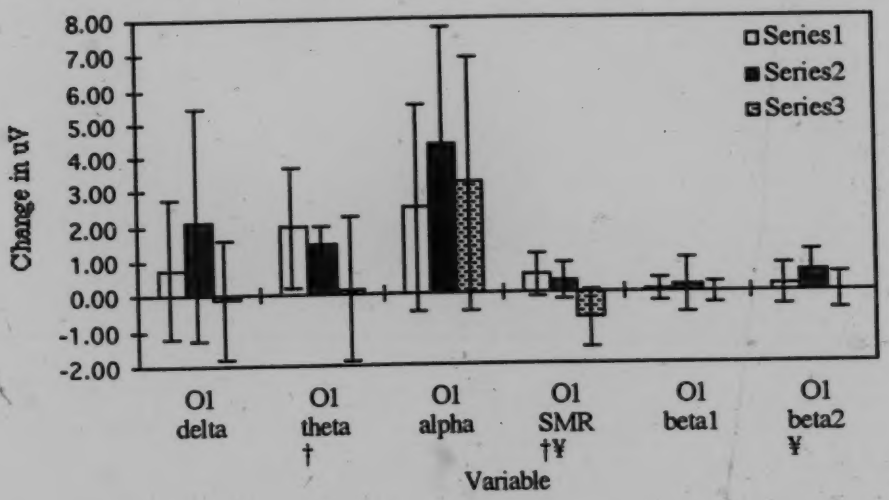
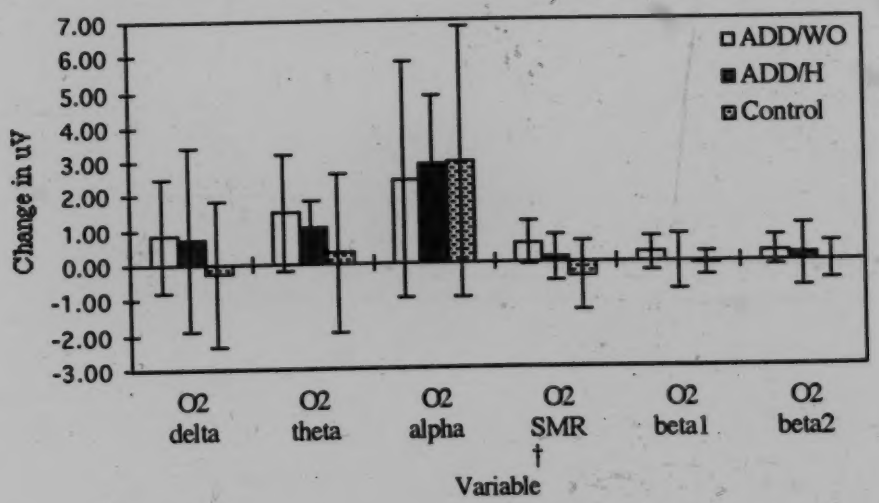


Figure 41. Change in magnitude standard deviation from eyes open to TOVA2 at O2.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 42. Change in magnitude standard deviation from eyes open to TOVA2 at P3.

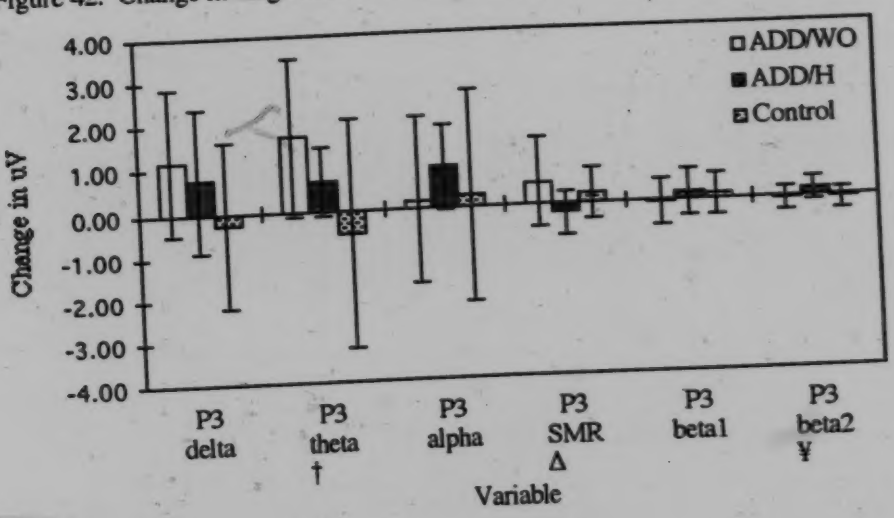
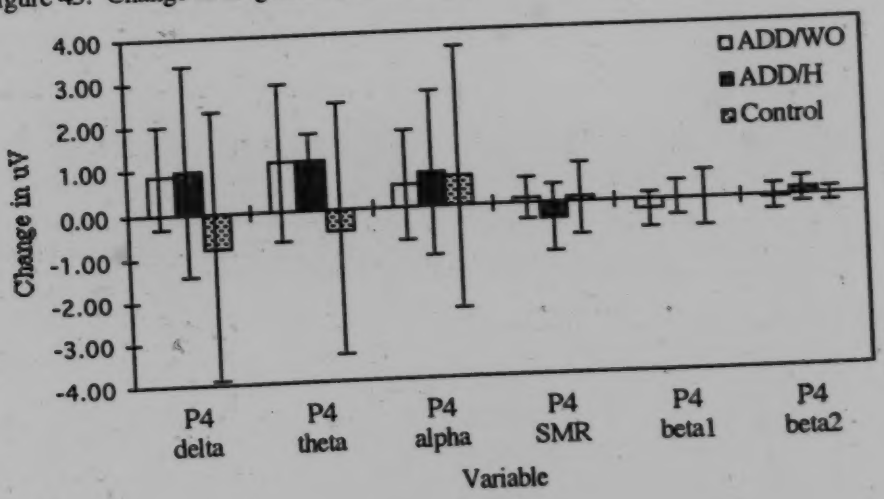
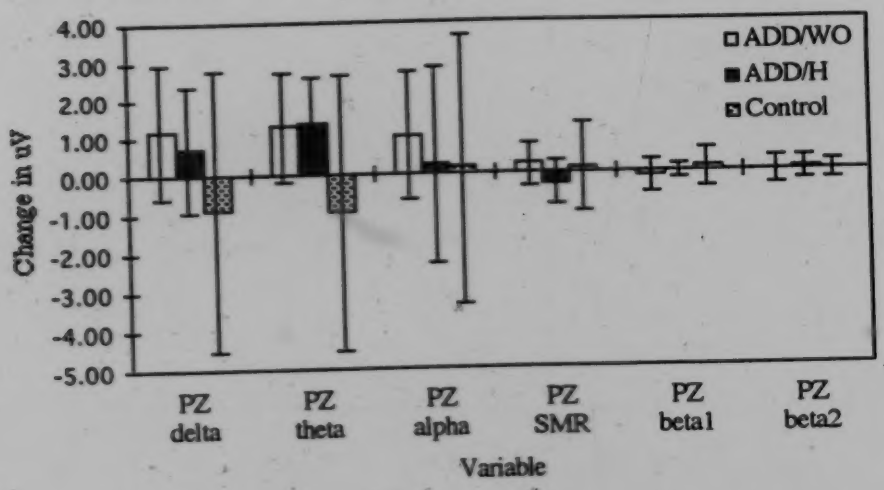


Figure 43. Change in magnitude standard deviation from eyes open to TOVA2 at P4.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Figure 44. Change in magnitude standard deviation from eyes open to TOVA2 at PZ.



Note. † denotes a significant difference between ADD/WO and control groups. Δ denotes significant difference between ADD/WO and ADD/H groups. ¥ denotes significant difference between ADD/H and control groups. Error bars indicate +/- one standard deviation. All comparisons at $p<.05$, $df = 2, 24$.

Rejected Epochs

As was mentioned previously, the EEG records for each subject were visually inspected and any epochs containing identifiable muscle artifact were discarded prior to the statistical analysis. Each epoch contains two seconds of data, and there were approximately 330 epochs (or 11 minutes) of data per subject collected for each of the TOVA1 and TOVA2 conditions. The mean number of rejected epochs for each group is presented in Table 9. A series of one-way analysis of variances ($df = 1, 16$) were used to analyze the group differences using an alpha level of .05. The number of epochs discarded for the ADD/H group during the

TOVA1 condition was significantly higher than for either the ADD/WO ($F = 7.38$, $p = .012$) or the control group ($F = 15.31$, $p = .001$). The difference between the ADD/WO and control subjects was not significant ($F = 1.43$, $p = .24$). Similarly, the number of epochs discarded for the ADD/H group during the TOVA2 condition was significantly higher than for the ADD/WO ($F = 7.26$, $p = .013$) or control groups ($F = 19.22$, $p = .000$). Once again the difference between the ADD/WO and control subjects was not significant ($F = 2.85$, $p = .10$).

Table 9. Number of epochs rejected during artifacting

	ADD/WO		ADD/H		Control	
	Mean	SD	Mean	SD	Mean	SD
TOVA1	196.78[a]	34.15	236.89[b]	26.26	179.11[a]	32.98
TOVA2	203.00[a]	39.21	254.22[b]	27.33	170.89[a]	50.94

Note. Means with different superscripts are significantly different at $p < .05$ level. $n = 9$ for each group. Means with different superscripts are significantly different at the $p<.05$ level. For each comparison $df = 1, 16$.

CHAPTER V

DISCUSSION

Behavior Rating Scales

As would be anticipated given the fact that the DSM-IV checklist was used to classify the subjects as either ADD/WO, ADD/H or control, there were a number of significant differences between the scores each group obtained on this measure. The ADD/H subjects were rated as being highly inattentive and hyperactive/impulsive, while the ADD/WO subjects only scored high on the inattention items. In comparison, the control subjects were rated as being relatively free from symptoms of either inattention or hyperactivity/impulsivity. From a practical standpoint, on average the parents of both clinical groups endorsed slightly more than eight of the nine DSM-IV inattention items as pretty much or very much describing their children. Conversely, while parents of the ADD/WO subjects endorsed an average of less than two of the hyperactivity/impulsivity items, the average number endorsed by parents of subjects in the ADD/H group was slightly greater than eight. The average number of items endorsed for the control subjects was just greater than one for the inattention items and less than one for the hyperactivity/impulsivity items.

Comparisons between the two clinical groups on the BASC reveals more similarities than differences. The significantly higher scores for the ADD/H subjects on the Hyperactivity and Aggression scales is consistent with previous research

(Dykman & Ackerman, 1991; Edelbrock et al., 1984), but none of the other comparisons were statistically significant. The ADD/H and ADD/WO groups were both rated as exhibiting similar levels of inattention, anxiety, and physical problems or complaints (somatization), and as possessing relatively limited leadership and social skills.

The ADD/H group received the highest mean rating on the Conduct Problems Scale, followed by the ADD/WO and the control groups. However, only the difference between the scores that were obtained by the ADD/H group and the control group was significant. It is possible that the sample size utilized in the present study was simply not large enough to replicate the findings of previous studies with respect to higher levels of antisocial behavior in ADD/H children as compared to those with ADD/WO (Berry, Shaywitz, & Shaywitz, 1985; Hynd et al., 1991; King & Young, 1982; Lahey et al., 1987). The ADD/WO subjects received a higher mean score than the ADD/H subjects on the Withdrawal scale, and while this is consistent with the findings of other researchers (Edelbrock et al., 1984; Lahey et al., 1984) this difference did not reach statistical significance. There was also a nonsignificant trend for the ADD/H group to be rated higher than the ADD/WO group with respect to the levels of depression and atypical behavior they display. While the Atypicality scale on the BASC is reported to be a measure of psychotic-type behavior (Reynolds & Kamphaus, 1992) it includes a variety of items that are commonly associated with inattentive and hyperactive behavior (e.g., daydreaming, stares blankly, rocking back and forth in a chair).

It is interesting to note that as a group the ADD/WO subjects were rated significantly higher than controls on the BASC Hyperactivity scale but not on the hyperactivity/impulsivity items that are included on the DSM-IV checklist. An examination of the individual items that are included on the BASC Hyperactivity scale reveals that many of them do not reflect what is typically thought of as hyperactivity. For instance, the Hyperactivity scale on the BASC Parent Rating Scale for 12 to 18 year olds includes items which reflect the need for a high level of supervision, the presence of temper tantrums, and the behavior of interrupting parents while they are talking on the telephone. Such items may well apply to children who do not exhibit hyperactive behavior as defined by DSM-IV criteria. However, if these items are endorsed by a parent they would contribute to an elevated score on the Hyperactivity scale, in some cases giving the false impression that hyperactivity is present when in reality this may not be the case.

A critical issue upon which the validity of the present research findings rests is whether the method of identifying ADD/H and ADD/WO subjects was appropriate. In this regard, the use of the DSM-IV checklist in selecting the subjects appears to have resulted in meaningful differences between the three groups. Support for this conclusion comes from two sources. First, the mean ratings on the BASC Parent Rating Scale were as expected given the composition of the three groups. Both the ADD/WO and ADD/H groups were rated as exhibiting significantly more emotional and behavior problems than the control group. There were also significant differences between the ADD/WO and ADD/H groups in that the latter subjects

scored higher on both the Hyperactivity and Aggression scales. Furthermore, these two groups were comparable on each of the remaining BASC scales including Attention Problems. Thus the primary difference between the two clinical groups according to the BASC results was in their levels of hyperactivity and aggression (as reported by their mothers), while they were similar with respect to problems of inattention. In contrast, the mean scores for the control group on all of the BASC scales fell within the normal range.

The second source of support is found in the number of EEG epochs that it was necessary to discard due to the presence of muscle artifact (which reflects movement, muscle tension, or both). The technician was not aware of each subject's group membership when the artifacting process was completed, and consequently the number of rejected epochs can be considered as an unbiased indication of the level of activity exhibited by each group during the EEG recording session. The ADD/H group had significantly more epochs rejected in both the TOVA1 and the TOVA2 conditions than either of the other groups, while the ADD/WO group and control group did not differ significantly from each other in this regard. The higher EEG epoch rejection rate in the ADD/H group can likely be attributed to their proclivity to be more physically active and fidgety than either normal or ADD/WO children. Consistent with the observations made during the recording session, these results indicate that as a group the ADD/H subjects were more restless during the collection of the EEG data than either the ADD/WO or the control subjects.

Psychometric Test Results

As was expected, the three groups are quite similar with respect to their scores on the intellectual and academic measures. The only exception was that the ADD/WO group scored significantly lower than the control group on the PSI of the WISC-III. Nevertheless, as a group the ADD/WO subjects achieved PSI scores that were still well within the average range. No other differences emerged between the clinical and control groups. This finding is inconsistent with previous research which indicates that ADHD subjects in general tend to score lower than normals on the FDI as well as the PSI (Anastopoulos, Spisto, & Maher, 1994; Prifitera & Dersh, 1993; Schwean, Saklofske, Yackulic, & Quinn, 1993). The lack of significant findings in this regard could well be attributed to the use of a relatively homogeneous sample in the present study. All subjects were required to have a Full Scale Intelligence Quotient that fell at or above 90, and this could have had the effect of partialling out potential subjects who may have achieved lower scores on the FDI and the PSI.

As expected, there were no significant differences between the ADD/WO and ADD/H groups on any of the WISC-III scores that were considered, and this finding is consistent with the majority of the research that has examined this issue (Ackerman et al., 1986; Barkley et al., 1990; Barkley et al., 1992; Berry et al., 1985; Frank & Ben-Nun, 1988; Hynd et al., 1991; Zagar et al., 1989).

Similar findings emerged with respect to the academic test results. Consistent with most of the previous research (Barkley et al., 1990; Carlson et al., 1986;

Dykman & Ackerman, 1991; Rubinstein & Brown 1984; Zagar et al., 1989) there were no significant differences between the ADD/H and ADD/WO groups, and the same held true with respect to the control group. Once again this finding would be expected since all of the subjects were required to achieve WIAT reading, spelling and mathematical reasoning scores that were within one standard deviation of the mean or higher, effectively reducing the variability in test scores and obscuring any differences that might otherwise exist between these groups of subjects.

Although the ADD/H subjects achieved considerably higher TOVA Variability scores (indicating greater impairment) than the ADD/WO subjects, there were no significant differences between the two clinical groups on any of the four TOVA variables. Both clinical groups achieved TOVA Variability scores that were higher than those obtained by the controls, but only the ADD/H subjects differed significantly from the control subjects in this regard. The Omission, Commission and Response Time variables were not significantly different for the three groups. However, examination of the mean T Scores for each group reveals a consistent trend for both the ADD/WO and the ADD/H groups to be more inattentive (as measured by the Omission scores) and impulsive (as measured by the Commission scores), to exhibit greater inconsistency in response times (as measured by the Variability scores), and to have longer response times than the control group. Thus the hypothesis regarding the utility of the TOVA in differentiating between normal and clinical subjects was partially supported by the data. According to Greenberg (1991), the Variability score is the most sensitive of the TOVA scores with respect to

the presence of ADHD. This certainly proved to be the case in the present study, particularly with respect to the ADD/H group. It is reasonable to assume that with a larger sample size and a commensurate increase in statistical power significant differences between the clinical groups and the control group may have emerged on other TOVA variables as well.

Since there were no differences between the two clinical groups the present findings suggest that the TOVA does not appear to be useful in differentiating between ADD/H and ADD/WO subjects. This conclusion is consistent with the majority of the existing research on continuous performance tests that measure errors of omission and commission (e.g., Barkley et al., 1990; Braun, 1992; Dykman & Ackerman, 1991; Holcomb, Ackerman, & Dykman, 1986) as well as reaction time (Dykman, Ackerman, & Oglesby, 1992; Holcomb et al., 1985, 1986; Hynd et al., 1989).

Greenberg (1991) suggests that if any one of the Omission, Variability or Response Time Scores are 1.5 standard deviations or more above the mean then a diagnosis of ADHD should be considered. Alternatively, if any two of these scores are one or more standard deviations above the mean then it would also be appropriate to consider a diagnosis of ADHD. (The Commission Score is excluded from this analysis since it is believed to reflect impulsivity and excessively high Commission scores tend to decrease scores on the other TOVA variables, thereby invalidating the test results.) Using these criteria, 77.8 % of both the ADD/H and ADD/WO subjects would be correctly classified, while only 55.5 % of the control subjects would be

correctly classified, resulting in an unacceptably high rate of false-positive classifications. Modifying the criteria to require that just one of the Omission, Response Time, or Variability scores be two or more standard deviations above the mean results in an identical hit rate of 77.8 % for the ADD/WO and ADD/H subjects with only 11.1 % of the control subjects being falsely classified.

These results suggest that the TOVA decision rules as described in the TOVA Interpretation Manual (Greenberg, 1991) may be too liberal, resulting in an unacceptably high number of false-positive classifications. In the small sample presented here, raising the criteria substantially reduced the number of false-positives while still maintaining an acceptable level of sensitivity to true-positive cases. However, it should also be noted that in the present study the TOVA was administered in a rather unique context (i.e., while the subjects were connected to the EEG equipment) and this may have had an impact on the scores that were achieved by each of the three groups. Consequently it would be inappropriate to generalize these findings beyond the current study without further examination of this issue under more typical TOVA administration conditions.

EEG Findings

The lack of differences between the two clinical groups on the EEG variables is perhaps the most noteworthy finding in the present study. Only three variables emerged as being significant from the analysis of covariance on the means, and only seven from the analysis of covariance on the standard deviations. In each case the

ADD/WO subjects exhibited either higher mean magnitudes or greater variability than the ADD/H subjects. The results were even less impressive for the change scores where only one of the mean magnitude change scores and four of the standard deviation change scores differentiated between these two groups. These findings were also less consistent than the analysis of covariance results, with the ADD/WO group exhibiting greater positive change in some variables and less of a change in others when compared to the ADD/H group. Overall there were a total of 15 significant findings out of a possible 528 comparisons (11 sites X 6 bands X 2 conditions X 2 variables X 2 scores), which is considerably less than would be expected by chance using an alpha level of .05.

The differences between the ADD/WO group and the control group were somewhat more definitive. Seventy-two out of a possible 528 comparisons emerged as significant. On each of these variables the ADD/WO subjects invariably displayed higher adjusted mean magnitudes or larger standard deviations than the control subjects. These results are consistent with those of other researchers who found that ADD/WO subjects exhibit higher overall magnitude when compared to control subjects (Mann et al., 1992; Janzen, 1992; Janzen et al., 1995). A similar pattern emerged from the change scores with the ADD/WO group constantly exhibiting larger increases in mean magnitude in both the TOVA1 and TOVA2 conditions. The same generally held true for the standard deviation change scores. On 14 of the significant comparisons the ADD/WO group displayed a larger increase in standard deviation, whereas the control group displayed a larger change on only two of the

variables. Moreover, a trend for the ADD/WO subjects to demonstrate more positive change scores than the control subjects even in the variables that did not emerge as significant is clearly evident in Figures 1 to 44.

An unexpected result was the relatively few number of significant differences between the ADD/H subjects and the control subjects. Only 26 out of a possible 528 comparisons emerged as significant. The ADD/H group differed significantly from the control group on nine of the variables from the analysis of covariance results for the means, and only one of the variables from the analysis of covariance for the standard deviations. However, all but two of the differences in means that emerged revealed higher amounts of slow wave (delta) activity for the ADD/H subjects, primarily in the occipital and parietal sites. The only exception was a higher beta2 magnitude at sites O2 and P3 for the ADD/H subjects during the TOVA2 condition. This finding of a predominance of slow wave activity in hyperactive children is consistent with what has been reported by other researchers (e.g., Callaway et al., 1983; Dykman et al., 1982; Gillberg et al., 1984; Harper et al., 1996; Janzen & Fitzsimmons, 1995; Matsuura et al., 1993).

With respect to the change scores, the ADD/H and control groups differed significantly on a total of 16 variables: eight from the changes in mean magnitude and eight from the changes in standard deviation. Once again, a consistent pattern emerged whereby the ADD/H subjects exhibited a greater shift to increased levels of delta than the control subjects, predominantly in the parietal and occipital sites. This same trend can be seen throughout the vast majority of the change scores in figures 1

to 22. The changes in standard deviation that emerged as significant were primarily in the SMR and beta2 bandwidths, and in all but one instance the ADD/H group displayed more substantial increases in variability than did the control group.

The paucity of significant findings between the ADD/H group and the control group may have been a consequence of the number of epochs that were rejected during the artifacting process and the data these epochs contained. As Table 9 illustrates, the number of epochs discarded due to the presence of unwanted artifact was significantly greater for the ADD/H group than for either the ADD/WO or the control group. With respect to the TOVA1 condition, after the artifacting process was completed there were 133 epochs left for the ADD/WO group, 151 for the control group, and only 93 for the ADD/H group. For the TOVA2 condition there were 127 epochs left for the ADD/WO group, 159 for the control group, and only 76 for the ADD/H group. It seems reasonable to assume that the ADD/H subjects, who had the largest number of epochs removed because of the presence of unwanted artifact, would have been more physically active during those times when they were having the most difficulty paying attention. If this assumption is correct then it is very likely that the rejected epochs may have contained more important data than the epochs that were retained. Along the same vein, it is also possible that the ADD/H group and the control group may have exhibited differences in some of the sites that were automatically excluded from the analysis because of a high incidence of artifact (FP1, FP2, F7, F8, T3, T4, T5, and T6). These possibilities also apply to potential differences that may exist between the two clinical groups. Once again, the large

number of discarded epochs, the excluded sites, and the information they contained may have been the most relevant to the issue of whether ADD/WO is a separate entity from ADD/H.

There was a clear trend for the clinical groups to achieve higher adjusted and obtained mean magnitudes than the control group on both the TOVA1 and TOVA2 conditions. The only exception was in the obtained means for the TOVA1 condition where the ADD/H subjects tended to achieve the lowest values out of the three groups. Gasser, Verlerger, Bacher, & Sroka (1988) used a cross-sectional design to study the EEG development in normal 6 to 17 year old subjects. They found that with the exception of alpha2 (defined as 9.5 to 12.5 Hz) all bandwidths steadily declined in absolute power as age increased. Viewed from this perspective, the trend for the clinical subjects in the present study to exhibit larger mean magnitudes than the control subjects may be interpreted as evidence of immaturity or a developmental lag. This interpretation is consistent with the conclusions of Matsuura et al. (1993) who calculated hypothetical ages based on EEG characteristics and found that ADHD subjects exhibited a maturational lag in brain function.

Consistent with what was hypothesized, the ADD/WO and the ADD/H groups also demonstrated higher mean magnitudes in the delta and theta bandwidths than did the control group. This was further punctuated by a tendency for the clinical groups to increase their production of slow wave activity more than the control group when shifting from the eyes open to the TOVA1 and TOVA2 conditions. Both delta and theta have been shown to decrease with increasing age throughout childhood

(Fenwick, 1985; Niedermeyer, 1987; Ornitz, 1991) and, as such, these findings would again be consistent with a maturational lag hypothesis.

An examination of Table 5 and Table 6 reveals that 71 percent of the significant differences in mean magnitude which emerged between the clinical groups and the control group for both the TOVA1 and TOVA2 conditions were found in the occipital and parietal sites. A similar situation exists with respect to the changes in mean magnitude where 66 percent of the significant differences occurred in these same sites. This finding is consistent with previous research (Hassan, 1995) and may be due, at least in part, to the fact that the TOVA is almost exclusively a visual task which requires the analysis of perceptual input: specifically the placement of a geometric shape within the entire gestalt. However, other researchers have also found that, compared to controls, ADD/WO subjects exhibit the greatest amount of slow wave activity in the posterior regions (Janzen, 1992, Janzen et al., 1995). The subjects in these studies were completing reading and drawing tasks which rely on a variety of cerebral processes as opposed to the TOVA which relies almost exclusively on visual processing. As such, it is possible that the preponderance of significant differences in the occipital and parietal sites may be more than simply a reflection of the task that was being completed during the collection of the EEG data, suggesting that these regions of the cerebrum may be implicated in the etiology of ADD/WO. This would be in keeping with the hypothesis that the parietal and temporal regions underlie the dysfunction associated with ADD/WO (Barkley et al., 1991; Schaughency & Hynd, 1989; Voeller, 1991). It is also interesting to note that the

number of significant findings between both of the clinical groups and the control group were more prevalent in the parietal and occipital sites. Specifically, 64 percent of the variables that were significantly different between the ADD/WO group and the control group were in the occipital and parietal sites, while the same was true for 81 percent of the variables that differentiated between the ADD/H and the control group. If this pattern of results can be attributed to more than simply the high visual-perceptual demands of the TOVA, then there may be reason to suspect that posterior regions may be implicated in the etiology of both ADD/WO and ADD/H. A more definitive answer in this regard will have to await further research.

Considering the results of the analysis of covariance and the change scores combined, there was a preponderance of significant differences between the clinical groups and the control group on the odd numbered EEG sites as opposed to the even numbered sites. Forty-four of the significant differences between the clinical groups and the control group occurred in odd numbered EEG sites, while 30 occurred in even numbered sites. Furthermore, odd numbered differences were more prevalent for both the ADD/WO and the ADD/H groups. Odd numbers correspond to placements on the left cerebral hemisphere and even numbers correspond to placements on the right cerebral hemisphere, thus indicating there were more differences between the clinical groups and the control group associated with the left hemisphere than with the right hemisphere. This finding is somewhat surprising given the prevailing belief that the right hemisphere is dominant for attention. Furthermore, one would expect the TOVA, which is a nonverbal task that requires

spatial analysis of geometric shapes, to be primarily a right hemisphere task. It may be that the change in cortical activation was more restricted to the right hemisphere for the clinical subjects than it was for the control subjects, thereby resulting in more significant findings in the left hemisphere. It may be that the pattern of cortical activation was more global or broad for the control subjects than it was for the clinical subjects, thereby resulting in more significant findings in the left hemisphere. Indeed, normal subjects have been found to exhibit activation of large portions of both hemispheres during the completion of tasks with high attentional demands (Dujardin et al., 1993), and the relative lack of global activation may be one of the characteristics that sets attention disordered subjects apart from normal subjects.

Conclusions

The results of the present study provide little support for the conceptualization of ADD/WO as a separate disorder from ADD/H. There were no unexpected differences between these groups on the BASC and while the ADD/H group did achieve a higher TOVA Variability score, this difference was not statistically significant. Although some differences between these groups did emerge on the EEG variables, they were no more prevalent than would be expected on a chance basis. Assuming that both ADD/WO and ADD/H subjects demonstrate similar EEG patterns that are characterized by the presence of excessive slow wave activity and higher mean magnitude when compared to normal subjects, what could account for the disparate behavioral characteristics they exhibit? The theory of optimal

stimulation (Zentall, 1975; Zentall & Zentall, 1983), which was originally postulated as an explanation for the behavior of hyperactive children, may be pertinent in answering this question. This theory assumes that for all organisms there exists "a biologically determined optimal level of stimulation. When that level of stimulation is not present, activity can serve as a homeostatic regulator. That is, an organism will initiate stimulation-seeking activity when there is insufficient stimulation" (Zentall & Zentall, 1983, p. 447). As with most psychological and physiological factors there are individual differences in the level of arousal that may be considered optimal. According to this theory hyperactive children suffer from a chronic state of underarousal, and their behavior represents an attempt at providing self-stimulation in order to maintain an optimal level of arousal. Essentially their level of activity is thought to be "an attempt to increase insufficient stimulation, rather than being a consequence of overwhelming stimulation" (Zentall, 1975, p. 552). Unfortunately, while the hyperactive behavior may have the desired effect of increasing the individual's level of arousal, it is often not conducive to learning and frequently interferes with the individual's ability to stay on task. From this theoretical framework, hyperactive behavior is not a consequence of an individual's physiological state, but a reaction to his or her physiological state. Similarly, distractibility may be conceptualized as an attempt to seek stimulation, while inattentiveness is a consequence of insufficient arousal necessary to sustain attention. The present findings and those of numerous previous EEG studies provide strong

support for the theory of optimal stimulation as an explanation for hyperactive behavior.

If the theory of optimal stimulation is correct in asserting that ADD/H children exhibit hyperactive behavior in an attempt to attain an optimal level of arousal, it follows that children who fit the criteria for ADD/WO may not exhibit hyperactive behavior because their level of arousal is already optimal for them, even though it may not be optimal in terms of their ability to function in their environment. Thus, while they are not hyperactive, they do present as being inattentive, sluggish, daydreamy, and disorganized. This explanation accounts for the differences in the level of activity these two groups exhibit, and also explains the relative lack of differences that has commonly been reported in the research literature: Evidence of such differences have not been forthcoming because they may not exist. Simply put, the difference between these two groups of children may be not in their cognitive or physiological characteristics per se, but rather in their response to their physiological state.

Limitations

The most obvious limitation of the present study is the small sample size that was utilized. Although it would have been preferable to include a larger number of subjects, it was felt that priority should be given to ensuring that the groups remained as pure as possible. From the outset it was recognized that identifying subjects who met the criteria for inclusion in the study would be a formidable task, and this

certainly proved to be the case. Indeed, it took approximately 21 months to complete the process of screening and evaluating potential subjects and collecting the EEG data.

A related limitation is the high risk of committing a Type I error in the analysis of the EEG data. The decision not to control for the risk of Type I error in favor of reducing the risk of committing a Type II error was a deliberate one based on the exploratory nature of the study and the importance of identifying potential differences between the two clinical groups. Given that relatively few differences emerged between the ADD/WO and ADD/H groups, it would appear that the risk of committing a Type I error was not a significant factor with respect to the primary research question. As was mentioned previously, true results have the characteristic of being reproducible (Duffy, 1989), and from this standpoint the differences that were detected between the clinical groups and the control group are buttressed by their similarities with what other researchers have found.

The subjects were not randomly selected from the population, but rather were included only if they met the criteria outlined in the methods section and they were willing to voluntarily participate in the study. Whether there were any important differences between individuals who were contacted but declined to participate and those who volunteered is unknown.

Finally, the impact of the relatively large number of rejected epochs for the ADD/H group on the final results is unclear. Although there is reason to suspect that

these epochs may have contained EEG data that differed somewhat from the epochs that were retained, the degree and nature of these suspected differences is unknown.

Suggestions for Future Research

The primary aim of this study was to provide direction for future investigations by identifying differences or trends between the EEG characteristics of ADD/WO and ADD/H subjects. Although the mean magnitude variables were the most proficient at distinguishing between the clinical groups and the control group, the standard deviations proved to be superior when comparing the ADD/WO subjects to the ADD/H subjects. It is also noteworthy that the Variability score on the TOVA proved to be the psychometric variable that best differentiated between the two clinical groups. Consequently it is recommended subsequent studies in this area include measures of within-subject variability.

Given that the majority of the differences between the clinical groups and the control group were on variables from the left hemisphere, it would not be advisable to focus exclusively on right hemisphere sites in future investigations. Rather, it would be prudent to include a variety of sites from both hemispheres. As was suggested previously, one of the differences between ADHD subjects and normal subjects may be the extent of cortical activation that they exhibit while completing tasks that require a high level of attention.

The calculation of change scores proved to be a useful method of examining the data which should be given consideration for inclusion in subsequent research. Over half of the significant differences that emerged were change scores, and

studying the shift in EEG activity that occurs when a subject moves from one activity to another may provide important insights into the dynamics underlying various attention and learning disorders.

Generalization from the present results to other EEG studies is made cumbersome by the fact that the observed EEG characteristics are to a large degree a function of the task that the subjects are engaging in at the time of the recording. As such the following suggestions apply only to studies that employ the TOVA, and to a lesser extent those that utilize similar tasks of visual attention. Based on the finding that the majority of the differences between the clinical groups and the control group were in the occipital and parietal sites it is recommended that future EEG research comparing ADHD subjects in general (whether ADD/H or ADD/WO) with normal subjects focus primarily on sites in the posterior regions. Utilizing a smaller number of sites, particularly P3, P4 and PZ, may also help to avoid the problem of rejected epochs: These are generally among the most artifact-free sites, and it may be possible to retain the vast majority of the epochs if they are the only sites considered in the artifacting process. Furthermore, most of the differences that did emerge were in the delta and theta bandwidths, and it would be advisable to examine these sites closely in any future research endeavors.

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APPENDIX A

GENERAL INFORMATION & HISTORY FORM

I. GENERAL INFORMATION

Child's Name: _____
last first

Birthdate: _____ Sex: _____
year month day

Name of Parent(s) with whom the child resides:

Father: _____
last first

Mother: _____
last first

Address: _____
Street City Province Postal Code

Phone (home): _____ Phone (work): _____

Does the child live with:

Biological Parents _____ _____
mother father

Adoptive Parents _____ _____
mother father

Step Parents _____ _____
mother father

If this child lives in a step family, how much time does he/she spend with the other biological parent?

_____

_____

Please list this child's siblings and their dates of birth. _____

_____

_____

_____

I. BIRTH & EARLY CHILDHOOD HISTORY

#1 Country of Birth: _____

#2 City or Town of Birth: _____

#3 Hospital of Birth: _____

#4 Were the biological parents of this child related to each other by blood in any way?

Don't know _____ Yes _____ No _____

#5 Biological mother's obstetrical history (mark an X in all appropriate boxes).

A _____ have no knowledge of biological mother's history
B _____ had difficulty becoming pregnant with this child
C _____ have experienced miscarriage Number _____
B _____ have experienced still birth Number _____

#6 Biological mother's obstetrical history (mark an X in all appropriate boxes).

A _____ have no knowledge of biological mother's pregnancy
B _____ German measles during the first 3 months
C _____ high fever during the first 3 months
D _____ excessive vomiting during the first 3 months
E _____ uterine bleeding or "spotting" during the first 3 months
F _____ high blood pressure
G _____ treatment for kidney problems
H _____ heart disease
I _____ chronic anemia
J _____ diabetes or suspected diabetes
K _____ surgery under general anesthesia
L _____ thyroid disease
M _____ drugs or medication during pregnancy. Specify _____
N _____ toxemia
O _____ uterine bleeding or "spotting" during the final 3 months
P _____ weight gain during pregnancy under 10 pounds
Q _____ weight gain during pregnancy over 30 pounds
R _____ induced labor

S _____ other; please specify _____

#7 Age of mother at the delivery of this child.

A _____ Don't know

B _____ under 16 years

C _____ 16 - 40 years

D _____ over 40 years. Actual age _____

#8 Length of pregnancy with this child.

A _____ Don't know

B _____ 28 weeks or less

C _____ 29 - 35 weeks

D _____ 36 - 40 weeks

E _____ over 40 weeks (child was overdue).

#9 Length of labor with this child.

A _____ Don't know

B _____ less than 8 hours

C _____ 8 - 19 hours

D _____ longer than 19 hours. Actual length _____

#10 Child's birthweight.

A _____ Don't know

B _____ less than 5.5 pounds

C _____ 5.5 - 8 pounds

D _____ more than 8 pounds. Actual weight _____

#11 Presentation at birth.

A _____ Don't know

B _____ Normal

C _____ Breech

D _____ Other; Please specify

_____

#12 Was the child born by cesarean section?

Don't know _____

Yes _____

Don't know _____

#13 Did birth cause any injury to this child?

A _____ Don't know

B _____ Yes; Please Specify _____

C _____ No

#14 Is this child a twin?

A _____ Don't know

B _____ Yes, 1st born

C _____ Yes, 2nd born

D _____ no

#15 Family history (please mark an X for all items which have been experienced by any of this child's blood relatives).

A _____ Don't have any knowledge of family history

B _____ early blindness

C _____ squint

D _____ early deafness

E _____ diabetes before age 40

F _____ mental retardation

G _____ mental illness

H _____ heart attacks before age 40

I _____ diagnosis of Attention Deficit Disorder

J _____ diagnosis of Hyperactivity

K _____ Other disorders; please specify _____

#16 Child's first week of life.

A _____ Don't know circumstances of birth

B _____ baby placed in a special nursery in hospital

C _____ baby stayed in hospital after mother went home

D _____ baby had breathing problems

E _____ baby given oxygen

F _____ baby jaundiced

G _____ baby given blood transfusion

H _____ baby had difficulty sucking

I _____ baby born with congenital abnormality or handicap; please specify _____

J _____ baby suffered convulsions while in hospital

K _____ baby had no serious problems

L _____ baby given medication(s); please specify _____

M _____ other problems; please specify _____

#17 Was this child breast fed?

A _____ Don't know

B _____ Yes How long? _____ weeks

C _____ No

#18 Weaning.

A _____ Don't know

B _____ no problem finding a suitable formula

C _____ tried several formulas

D _____ weaned to a cup

#19 Appearance of child during first few weeks after birth

A _____ Don't know

B _____ normal appearance, healthy

C _____ pale, delicate looking

D _____ other; please specify _____

#20 In infancy, did this child reach out to prepare himself to be picked up when a parent approached him?

A _____ Don't know

B _____ yes

C _____ no

#21 At what age did this child first sit unsupported (sitting at least one minute without the use of his/her arms for support)?

A _____ Don't know

B _____ before 5 months

C _____ 5 - 8 months

D _____ after 8 months

#22 At what age did this child first walk unsupported (at least 10 steps)?

A _____ Don't know

B _____ before 11 months

C _____ 11 - 15 months

D _____ after 15 months

#23 At what age did this child begin to use words in a meaningful way?

A _____ Don't know
B _____ was using words by 1 year
C _____ was using words by 1 1/2 years
D _____ was using words by 2 years
E _____ was using words by 2 1/2 years
F _____ not until after 2 1/2 years

#24 At what age did this child begin putting 2 words together?

A _____ Don't know
B _____ by 1 year
C _____ by 1 1/2 years
D _____ by 2 years
E _____ by 2 1/2 years
F _____ by 3 years
G _____ after 3 years

#25 At what age did the child begin using short sentences?

A _____ Don't know
B _____ by 1 1/2 years
C _____ by 2 years
D _____ by 2 1/2 years
E _____ by 3 years
F _____ after 3 years

II. HISTORY OF ILLNESS

#26 Please check all of these the child has experienced.

A _____ mumps
B _____ German measles
C _____ red measles
D _____ chicken pox
E _____ scarlet fever
F _____ whooping cough
G _____ chest problems Specify _____
H _____ heart trouble Specify _____
I _____ allergies Specify _____

J _____ unusual reactions to vaccinations: Specify _____

K _____ disorders requiring surgery: Specify

_____

L _____ meningitis or encephalitis

M _____ poliomyelitis

N _____ serious head injury with loss of consciousness

O _____ convulsions/seizures

P _____ fainting

Q _____ accidental poisoning

R _____ failure to thrive

S _____ sleep disturbances

T _____ hospital admissions. How many be age 3 _____.

U _____ others; Please specify _____

#27 Has this child received regular immunization shots and vaccinations?

A _____ Don't know

B _____ Yes

C _____ No

#28 Does his child have any serious or chronic health problems at present?

No _____ Yes _____

If yes, please describe. _____

_____

_____

#29 Is this child taking any medication on a regular basis at present?

No _____ Yes _____

If yes, please indicate the drug, dosage, and reason prescribed. _____

_____

_____

_____

#30 Has this child been hospitalized, or undergone surgery where general anesthesia was given?

No _____

Yes _____ Number of hospitalizations _____

If yes, please describe. _____

_____

_____

III. OTHER INFORMATION

#31 any Has this child had any difficulty with the following? Mark an X in front of that apply. Mark an X in the space after the item if it is still a concern.

A _____ speech/articulation problems _____

B _____ language difficulties _____

C _____ memory problems _____

D _____ motor clumsiness _____

E _____ enuresis _____

F _____ psychological trauma _____

G _____ others; please specify _____

#32 Is English this child's first language? Yes _____ No _____

If no, what languages are spoken at home _____

in school _____

#33 Is this child in a language immersion program at school?

No _____ Yes _____ Language _____

#34 Would you say your child has difficulty sustaining attention?

No _____

Yes _____

#35 Does this child display hyperactive behaviors?

A _____ most of the time

B _____ some of the time

C _____ rarely

#36 Who is this child's physician?

_____

IV. EMOTIONAL FUNCTIONING

#37 Please check the items which best describe this child's emotional functioning at this time.

A _____ seems generally happy and has fun
B _____ cries easily
C _____ oversensitive to criticism
D _____ worries excessively
E _____ has extreme fears / frightens easily
F _____ seems frequently sad / unhappy
G _____ appears nervous / tense
H _____ handles ups and downs easily
I _____ seems to be inhibited or bottles things up
J _____ expresses anger
K _____ others; if you wish to elaborate or add to any of the above please do so in the space provided. _____

_____

_____

#38 Please check the items which best describe this child's personal relationships.

A _____ gets along well with other children in a group
B _____ relates well to children one on one
C _____ has difficulty relating with other children
D _____ is often aggressive or teases others
A _____ has few friends
B _____ has many friends
C _____ can share things easily
D _____ is frequently getting into fights
A _____ bosses other children around
B _____ gets picked on by other children
C _____ seems to enjoy helping others
D _____ relates well to adults

A _____ has difficulty relating to adults

B _____ other; please describe _____

_____

_____

Please write down any additional concerns / comments you may have regarding this child. _____

_____

_____

_____

_____

_____

THANK YOU FOR TAKING THE TIME TO FILL OUT THIS QUESTIONNAIRE. PLEASE BE ASSURED THAT ALL OF THE INFORMATION CONTAINED WITHIN THIS FORM WILL BE HELD IN THE STRICTEST CONFIDENCE.

APPENDIX B

DSM-IV CHECKLIST

Child's Name _____ Date _____

Please indicate the degree to which each of the following characteristics describes your child when he is not taking medication for ADHD.

	Not at all	Just a little	Pretty much	Very much
1. Often fails to give close attention to details or makes careless mistakes in school work, or other activities	____	____	____	____
2. Often has difficulty sustaining attention in tasks or play activities	____	____	____	____
3. Often does not seem to listen when spoken to directly	____	____	____	____
4. Often does not follow through on instructions and fails to finish schoolwork or chores (not due to oppositional behavior or failure to understand instructions)	____	____	____	____
5. Often has difficulty organizing tasks and activities	____	____	____	____
6. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)	____	____	____	____
7. Often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)	____	____	____	____
8. Is easily distracted by things around him or her	____	____	____	____
9. Is often forgetful in daily activities	____	____	____	____
10. Often fidgets with hands or feet or squirms in seat	____	____	____	____
11. Often leaves seat in classroom or in other situations in which remaining seated is expected (e.g., mealtime)	____	____	____	____
12. Often runs about or climbs excessively in situations in which it is inappropriate	____	____	____	____
13. Often has difficulty playing or engaging in leisure activities quietly	____	____	____	____
14. Is often "on the go" or acts as if "driven by a motor"	____	____	____	____
15. Often talks excessively	____	____	____	____
16. Often blurts out answers before questions have been completed	____	____	____	____
17. Often has difficulty awaiting turn	____	____	____	____
18. Often interrupts or intrudes on others (e.g., butts into conversations or games)	____	____	____	____

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APPENDIX C

SAMPLE REPORT

Confidential Psychological Assessment Summary

Name:	XXX
Date of Birth:	October 16, 1984
Age:	10 years, 8 months
Parents:	
Address:	
Phone:	
Date of Assessment:	June 17, 1995
Date of Report:	September 4, 1995

XXX was assessed as part of a research project designed to examine the differences between children with Attention Deficit Hyperactivity Disorder (ADHD) who exhibit the hyperactive component and those who do not. He has previously been diagnosed as ADHD (Combined Type) and although he has been prescribed medication for this condition, he was not taking any on the day of the assessment.

Observations

During the testing session it was noted that XXX was a persistent worker. However, he tended to overreact to situations where the test items became difficult and reacted quite negatively when he was unable to provide an appropriate response. In addition, he exhibited a variable pattern of correct and incorrect responses, which may have been due to an inability to sustain attention consistently over time. On the basis of these observations and the fact that he had not taken any medication, it is possible that the following test results are an underestimate of his true potential.

Tests Administered

Wechsler Intelligence Scale for Children - Third Edition
Wechsler Individual Achievement Test (Screening Form)
Test of Variables of Attention
Behavior Assessment System for Children (Parent Report Scale)
ADHD Checklist
SNAP Behavior Rating Scale

Test Results

Intellectual Functioning:

The Wechsler Intelligence Scale for Children - Third Edition (WISC-III) is a measure of general intellectual functioning which allows for a comparison between a student's verbal and nonverbal intellectual abilities. XXX obtained a Full Scale

intelligence quotient (IQ) that placed him within the Average range of general intellectual functioning. His overall score fell at the 32nd percentile, indicating that he performed better than 32 percent of the individuals his own age. As was mentioned previously, it is quite possible that he may have scored somewhat higher had he been medicated on the day the testing took place. His Verbal and Performance IQ's were not significantly different, suggesting that his language comprehension and verbal reasoning abilities are roughly equivalent to his nonverbal problem-solving skills.

His score on the Verbal Scale of the WISC-III fell at the 42nd percentile, representing an Average level of functioning. XXX did well on tasks that measure the ability to understand verbal concepts, immediate auditory memory, and social judgment. In contrast, he experienced difficulty on tasks that assess one's knowledge of factual information and understanding of word meanings. In general, he appears to possess an adequate command of the English language when compared to other students his own age. Since the Verbal Scale is considered to be a good predictor of future academic success, these results suggest that with an appropriate amount of motivation and effort XXX should be capable of progressing at a normal rate in school.

XXX's score on the Performance Scale also placed him within the Average range of functioning and fell at the 27th percentile. He had difficulty on timed tasks that required the ability to work quickly, and as a result he rarely earned bonus points that are awarded for fast performance. XXX's ability to process visual information quickly appears to be a weakness for him, but he did quite well on a sequencing task that requires the ability to analyze and interpret cause and effect relationships.

Academic Functioning:

The Screening Form of the Wechsler Individual Achievement Test was administered to provide an estimate of XXX's basic academic skills. He achieved an Average rating with respect to his reading (word recognition), spelling and arithmetic skills. These results are consistent with what would be predicted given his level of intelligence as estimated on the WISC-III and do not indicate any significant academic deficits at this time. As such there is no evidence of any specific learning disability.

Attention & Impulsivity:

XXX was asked to complete the Test of Variables of Attention (TOVA), which is a computerized measure of attention and impulsivity. The results suggest that he displays a strong tendency to respond in an impulsive manner, indicating that he was often unable to stop himself from responding in cases where a response was inappropriate. Such children typically act without thinking, and this often creates difficulty for them in both academic and social situations. Interestingly he did not appear to have any serious difficulties paying attention during this task.

Behavior Rating Scales:

XXX's mother completed a Parent Rating Scale that is designed to provide an overview of a child's behavioral and emotional characteristics. The items that

were endorsed suggest that he lacks self-control, and often displays disruptive behaviors. He may be prone to act in an aggressive manner, being argumentative and making both verbal and physical threats towards others. Rule breaking and damage to physical property may also be common. An extreme level of hyperactivity was suggested, as was a strong tendency to act without thinking. Such children are easily distracted and are typically unable to concentrate for more than a few minutes at a time. XXX may sometimes exhibit signs that he is unhappy or sad. A lack of social skills and difficulties relating with his peers was also suggested.

Two additional rating scales which are comprised of symptoms that are used to diagnosis ADHD were also completed by XXX's mother. The results suggest that when XXX is not taking his medication he exhibits very high levels of inattention, impulsivity, and hyperactivity compared to other children his own age.

Conclusions and Recommendations

The results of the assessment are consistent with a diagnosis of ADHD (Combined Type). Although this would likely have a negative impact on his ability to perform up to his potential in an academic setting, there was no evidence to suggest that XXX has a specific learning disability. Any difficulties that he may experience in school are likely attributable to his ADHD rather than to any specific academic deficits or to limited intelligence.

ADHD is an neurological disorder which appears to be associated with a low level of central nervous system arousal. This state of "underarousal" leads to a variety of problems including difficulties with concentration, stimulation seeking behavior (distractibility, hyperactivity, etc.), and impulsivity or a reduction in the ability to inhibit behavior. The use of medication to reduce these symptoms certainly seems to be warranted for XXX. Professional counselling directed at reducing XXX's level of anger and frustration may also be beneficial. Such services can be accessed either through the University of Alberta Education Clinic (492-3746) or the Child & Adolescent Services Association (438-0011).

The following are general recommendations for parents and teachers of ADHD children who exhibit both inattentive and hyperactive behavior.

Suggestions for Parents

1) Don't blame the child for the ADHD symptoms. Remember that it is a neurological disorder and be careful to distinguish between intentional misbehaving or noncompliance on the one hand, and the out of control behavior that is caused by ADHD on the other.

2) Place a high priority on family relationships. Take time to develop a good relationship with your children and make sure that there are a sufficient number of positive experiences to offset the negative ones. Parents should also take time to nurture their relationship with their spouse since the frustrations associated with raising an ADHD child can take its toll on a marriage.

3) Recognize that your child may be even more frustrated than you are. Choose positive reinforcement over punishment whenever possible since punishment often

leads to further frustration. In addition, give your child ample opportunity to express his or her frustration in an appropriate fashion.

4) Avoid unnecessary conflicts and be careful not to get into a pattern of confrontations about every little thing. Some issues are just too small to worry about and it is better decide which issues are really important and concentrate your efforts on these. It is not worth increasing frustration levels and possibly ruining a relationship over things that simply annoy you.

5) Stay calm!! Getting angry and upset often only serves to escalate the intensity of the child's behavior. Adults should endeavor to provide an example of how to handle conflict in an appropriate fashion.

6) Behavior modification programs that are designed to encourage on task behavior are often useful. However, it is necessary to use a highly structured reinforcement system if such programs are to be effective with ADHD children. Choose positive reinforcement rather than punishment whenever possible since punishment often serves to increase the child's level of frustration. In addition, it is necessary to make the connection between behavior and consequences very explicit, to deliver consequences (both positive and negative) immediately and on a continuous reinforcement schedule, to use rewards that are very powerful or salient, and to change the type of reward frequently. The use of home reinforcement programs (where the student is rewarded at home for their behavior in school) can be a useful adjunct, but their effectiveness is often limited because of the delay between the behavior in question and the reward.

7) Due to the impulsivity and poor self-control that many ADHD children exhibit, they are more likely than other children to copy aggressive or violent behavior. In general, the more aggression they are exposed to the more likely they will be to display aggressive behavior. Closely monitoring and limiting the types video games, movies, and television programs they watch can be an important factor in reducing the amount of aggression they exhibit.

8) Support groups such as The Attentional Disorders Association (TADA) can provide
a good deal of encouragement and information to parents of ADHD children. Information regarding the services and meetings sponsored by TADA can be obtained by calling 988-3960.

<u>Suggestions for Teachers</u>

1) Anticipate problems. Having back-up materials and activities available can help to prevent difficult situations from arising. Transition times between activities or classes are often difficult, so make sure the student knows what is expected in each new setting (which rules apply etc.).

2) Increase the amount of structure in the classroom as much as possible. Have each minute of the day planned, with little or no "free time" and clearly defined rules and consequences.

3) Attempt to reduce the number of distractions in the classroom to a reasonable level (i.e., do not place them in "open" classrooms), but take care not to create a sensory deprived environment. Cubicles which are designed to block out distracting stimuli are typically not effective since they often result in stimulation seeking behavior. Although they sometimes keep the child from disturbing the rest of the class, they rarely result in increased academic output.

4) Arrange for preferential seating close to the teacher and use gentle physical touch or contact with the student's desk to gain his or her attention.

5) Keep directions short and simple, and have the student repeat them to make sure he or she was listening. Make eye contact and ensure the child is attending before you communicate with him. This will help to avoid misunderstandings and unnecessary frustration.

6) Be creative! Use novel tasks and methods of presentation. The more exciting the presentation, the better they will learn and the more manageable their behavior will be.

7) Increase the stimulus value of classroom materials by using manipulatives and high interest materials, and by varying the color, style, and size of words, letters and numbers, etc. Important material should highlighted and made to stand out in a way that will draw their attention to it.

8) Change tasks frequently to help keep the interest level high. Assignments should be brief to help build a sense of accomplishment and get the child used to the idea of working until something is completed. A few five minute tasks will generally result in more learning than one thirty minute task. After a while you will have a sense of how long the child can concentrate, and try to keep your expectations within these limits.

9) Give them only one thing to do at a time, and attempt to intersperse low interest tasks with high interest ones.

10) Use a cueing system to direct the child's attention back to the work. This may be a special signal from the teacher or a timer that goes off at regular intervals and reminds students to ask themselves "what am I doing right now," and "what should I be doing."

11) Give students time limits to help keep them on task. It is often useful to have students estimate the amount of time it will take to complete an assignment, and then have them work against the clock to see whether they can actually meet their own expectations. This type of competition against oneself can be highly motivating for some students, and the emphasis on time often helps them to focus their attention on the work they are doing.

12) Consider matching specific students with specific teachers whenever this is an option. Hyperactive children often need hyperactive teachers who can keep up with them, but it is also important to have a teacher who is well organized, flexible, and displays patience with this type of child.

Thank you for the opportunity to work with XXX. If you have any questions about the contents of this report please do not hesitate to contact me.

_____

Garth Stewart, M.Ed., C. Psych. (#2118)

APPENDIX D

INFORMATION AND CONSENT FORM

Dear parent:

I would like to invite you and your child to participate in a research project that is being conducted at the University of Alberta. The purpose of the research is to study the characteristics of children with two types of Attention-Deficit Hyperactivity Disorder (ADHD): those with the hyperactive component and those without hyperactivity. In addition to providing theoretical information regarding the classification of behavior disorders, it is also hoped that the results of the study will help to determine whether these two groups of children should be managed in a similar manner or whether they represent two distinct groups that require different methods of treatment.

For the purposes of the study it is necessary to identify children who meet the criteria for ADHD, but who also have at least average intelligence and no specific learning disability in reading, spelling, or arithmetic. Of course, most of the participants will be experiencing some degree of academic difficulty, but the reason for these problems should be their inattention, impulsivity, or hyperactivity, rather than a specific learning disability. Appropriate intellectual and academic testing will be provided to ensure that all participants meet the criteria for entrance into the study. In some cases much of this information may already be available, and therefore it may not be necessary to complete all of the testing if a psychological assessment has been conducted within the past year. All subjects must also be right handed males who are 10 to 12 years of age. Parents will be asked to complete a series of behavior rating scales and an information sheet detailing the medical and developmental history for each child. Selected children will then be asked to participate in the completion of an electroencephalographic (EEG) assessment. A nylon cap with sensors attached to it will be placed on the child's head, and the child will be asked to complete a series of tasks while the electrical impulses generated from the brain are recorded. This procedure causes little or no discomfort to the child, and most children find the experience quite interesting and educational. An additional requirement will be for all children to be free from any medication used to treat ADHD on the day of the EEG assessment, and as such it may be necessary to obtain the consent of their physician in order to arrange this.

The testing and the EEG assessment will be provided at no cost to the participant, and a written summary of the psychological test results (intellectual, academic and behavioral measures) with any appropriate recommendations will be mailed to you upon completion of the project. All of the information that is obtained during the study will be kept strictly confidential, and the names of the individual participants will not be released. In addition, should you and your child decide to participate in the study, either of you may choose to withdraw at any time.

If you and your child wish to participate in this study, please sign the attached consent form and complete the enclosed rating scales and return them to me in the

envelope provided. Should you require additional information before you decide, you can reach me at 474-0341.

Thank you for your time and consideration.

Respectfully,

Garth Stewart
M.Ed., C. Psychologist

Consent Form

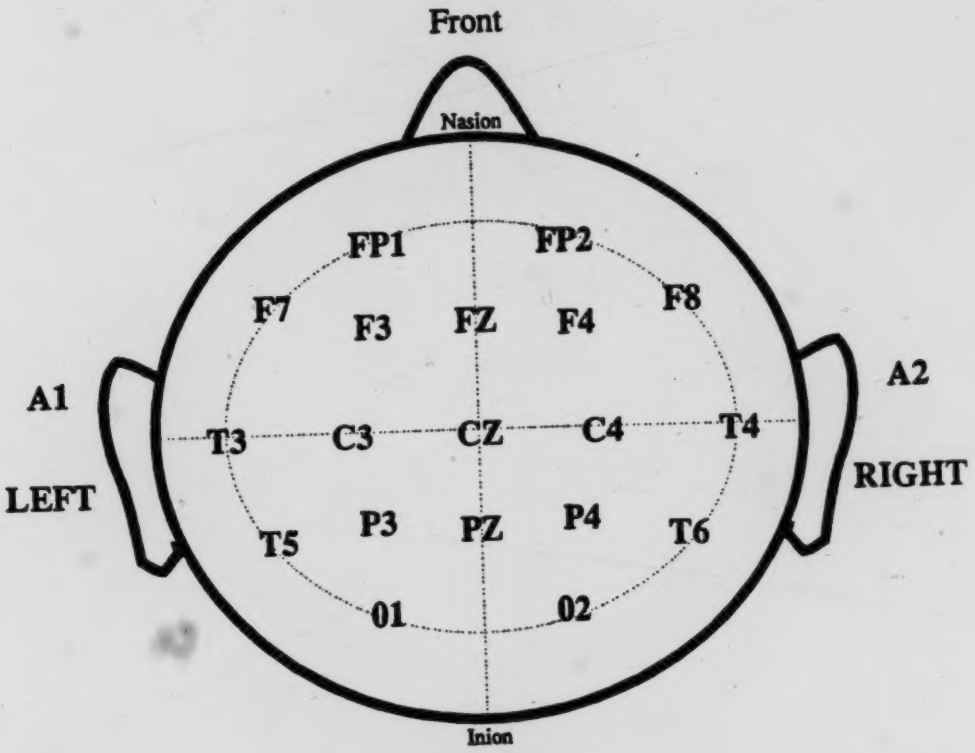
I have read the attached information letter and hereby give my permission for _____ to participate in a
(your child's name)
research project which consists of a psychological and electroencephalographic (EEG) assessment conducted by Garth Stewart under the supervision of a University of Alberta academic staff member. If necessary, I also give my permission for the researcher to contact my child's physician to facilitate a brief discontinuance of any medication used to treat his Attention-Deficit Hyperactivity Disorder. I understand that even after the study has commenced, I or my child can choose to withdraw from the research project at any time.

Parent's signature _____ Date _____

Child's signature _____ Date _____

APPENDIX E

INTERNATIONAL 10-20 SYSTEM



Legend

F = Frontal
C = Central
T = Temporal
P = Parietal
O = Occipital

odd numbers = left hemisphere
even numbers = right hemisphere
Z = midline

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